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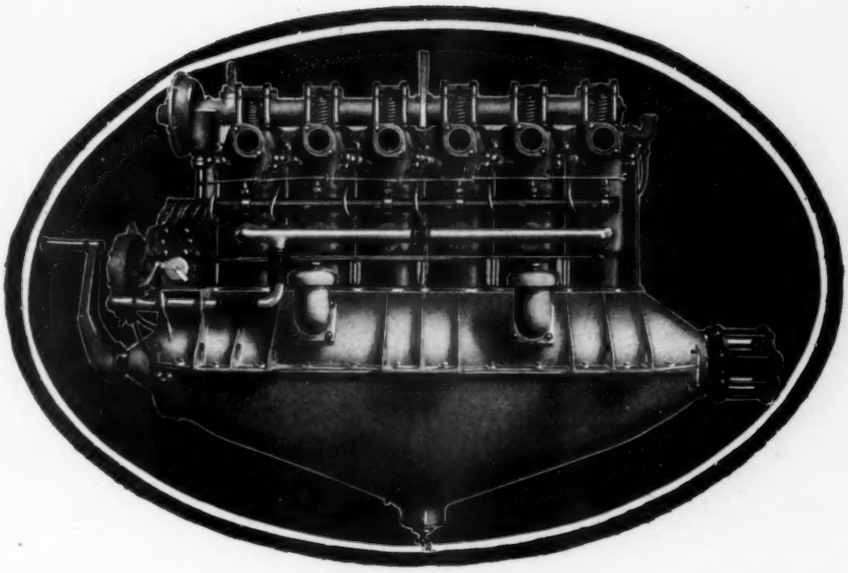

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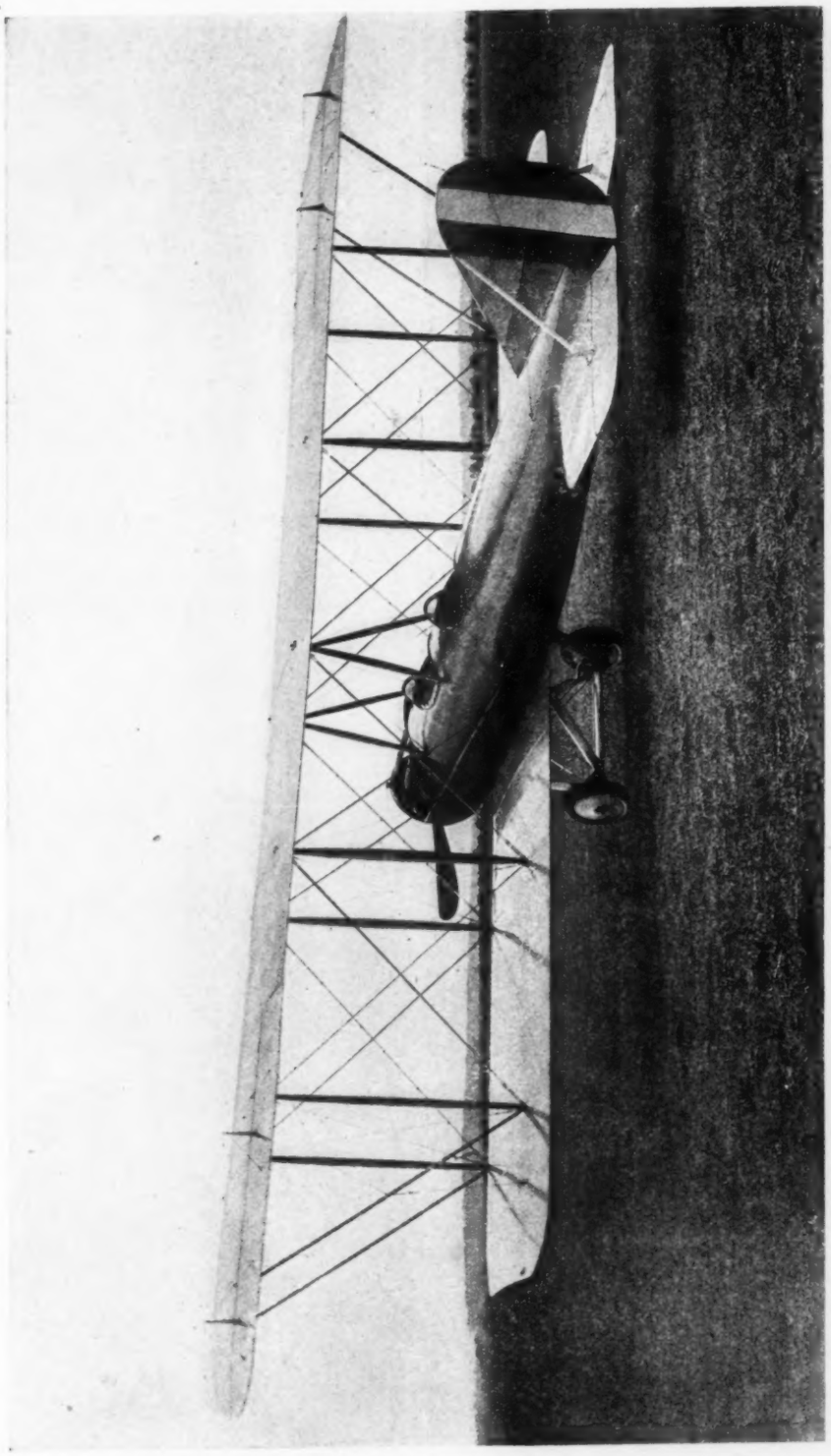

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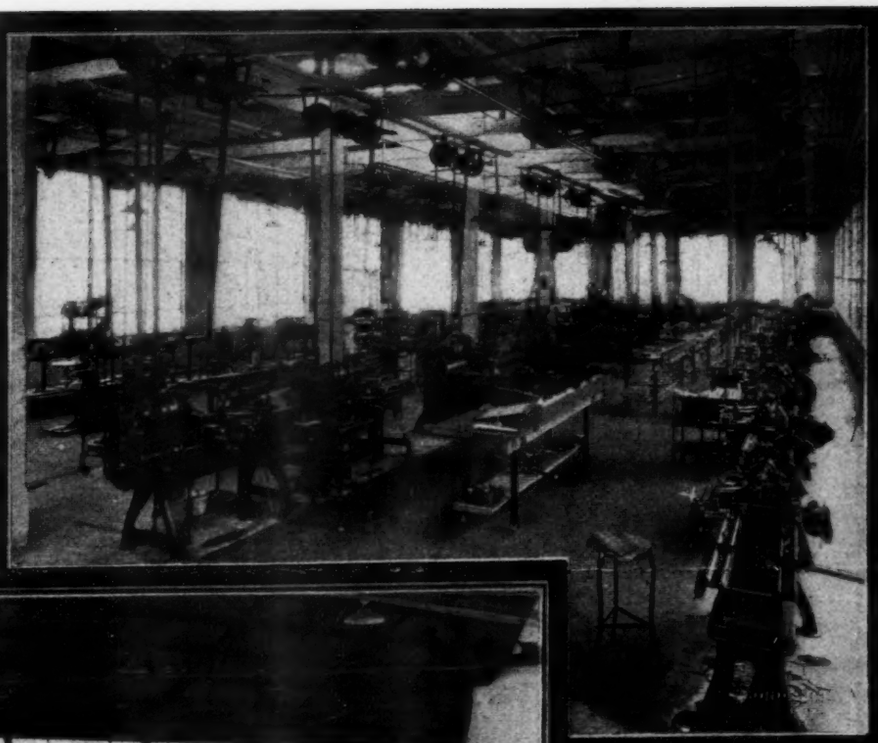

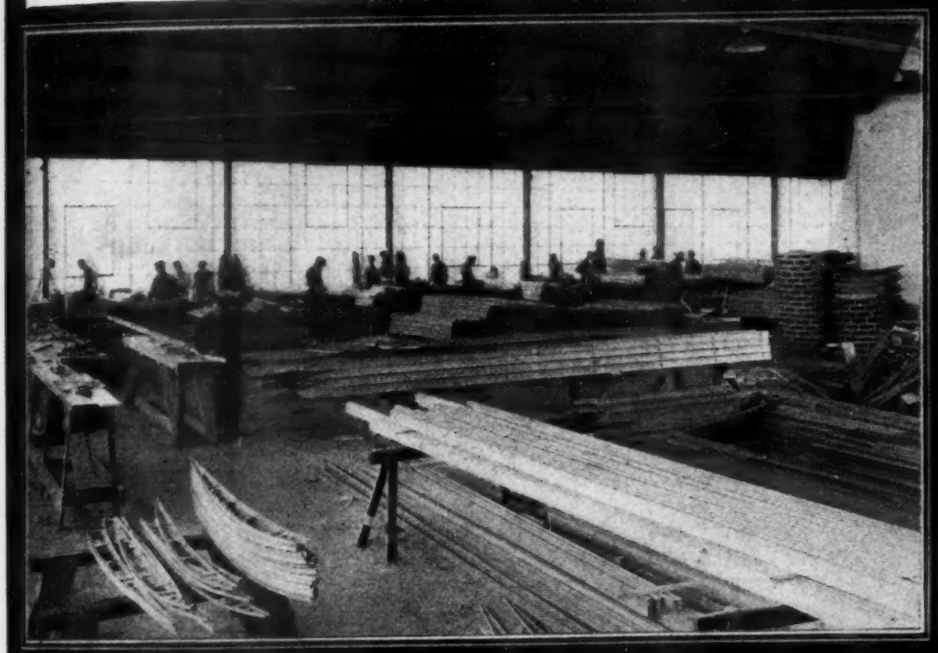

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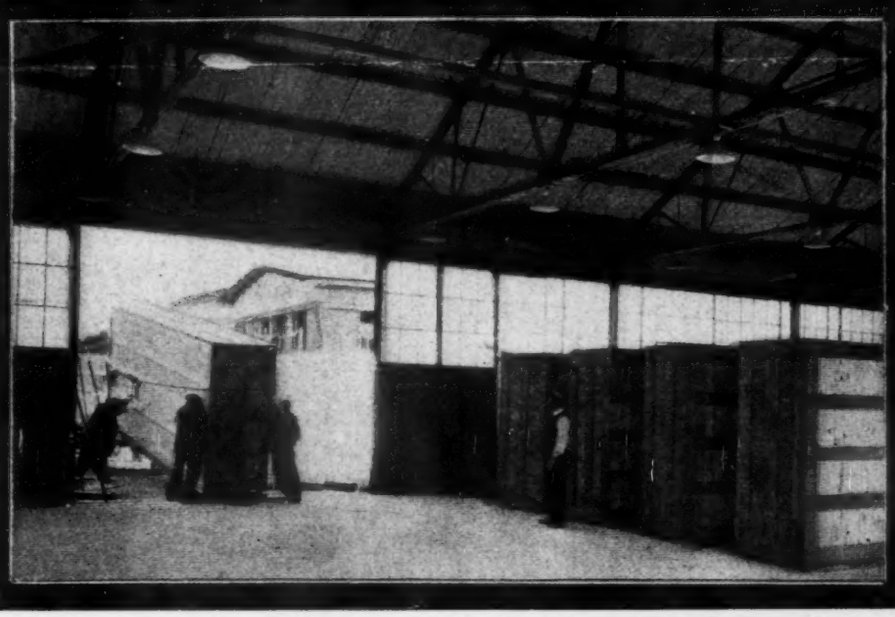

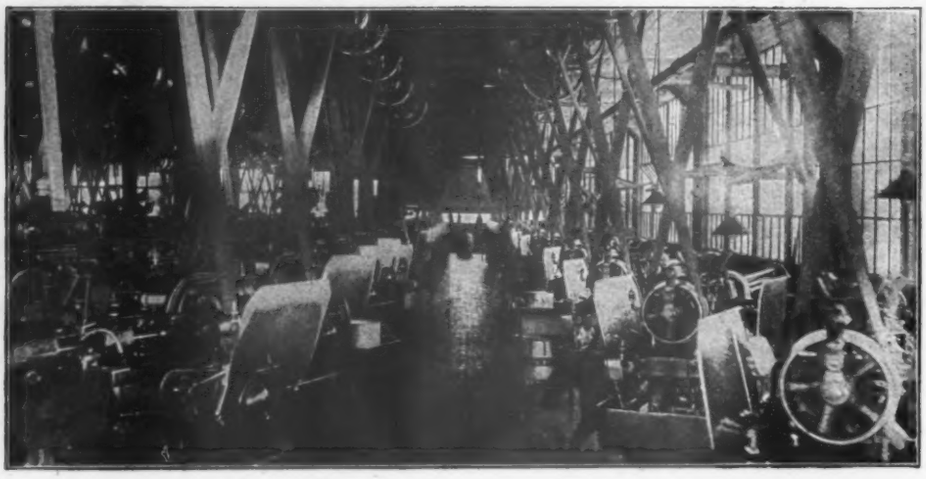

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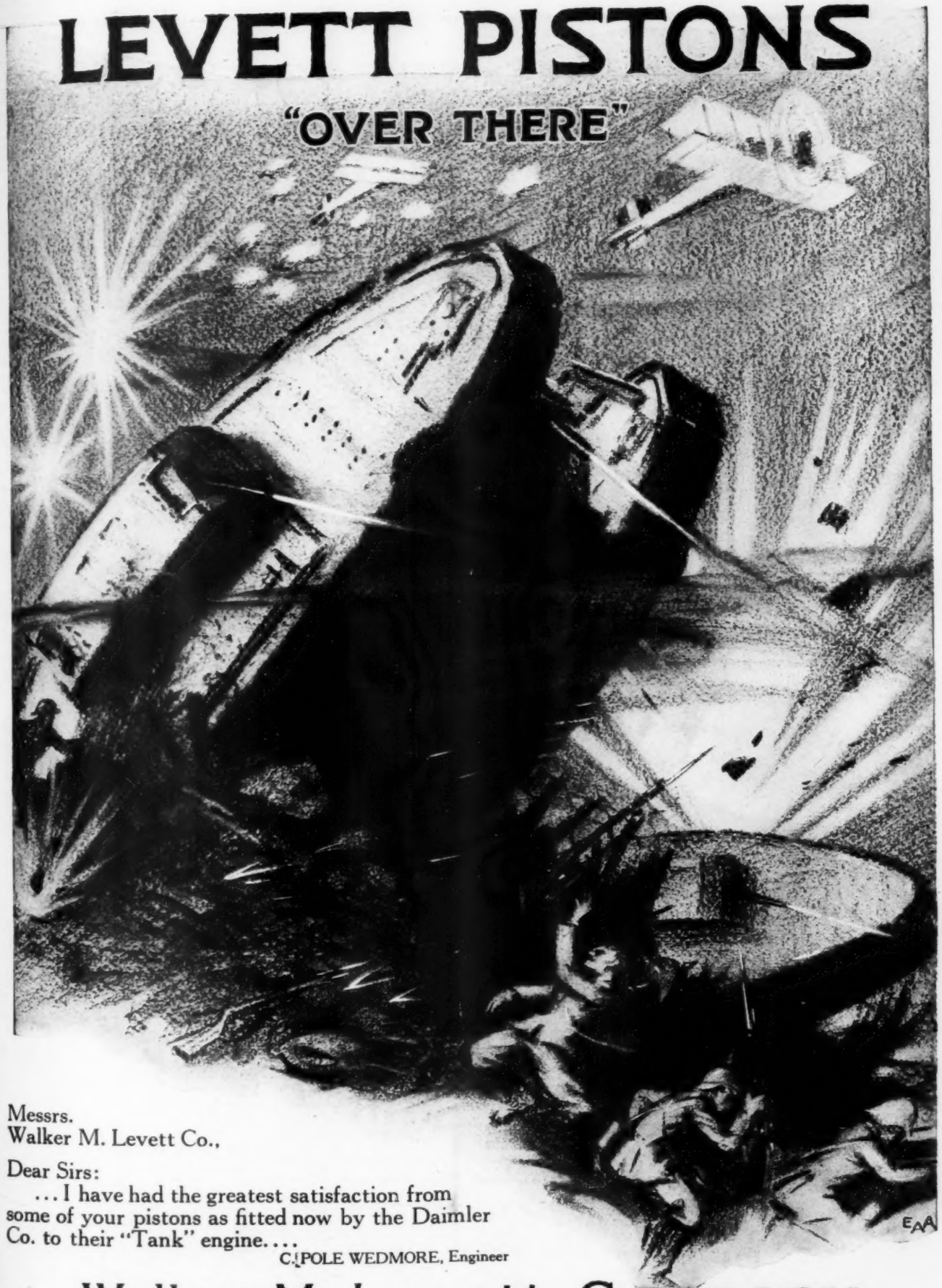

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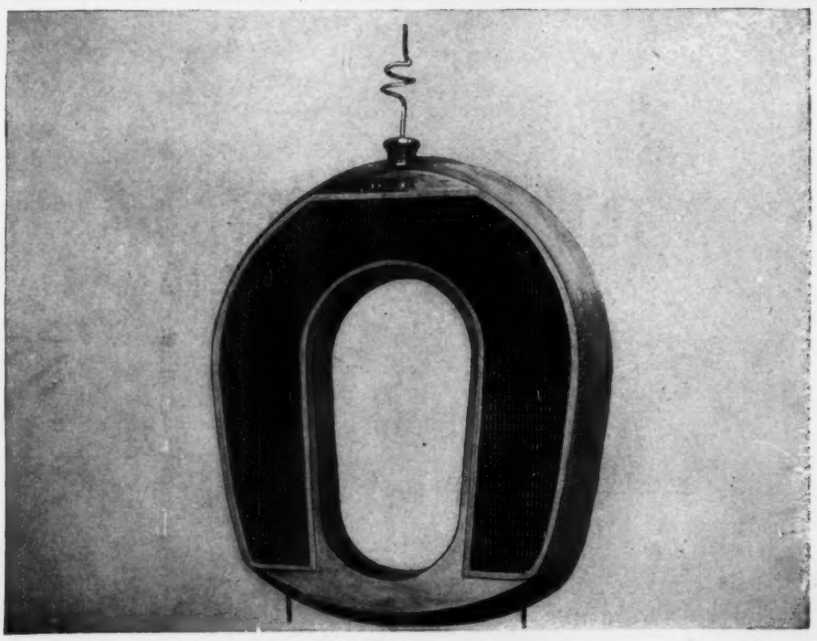

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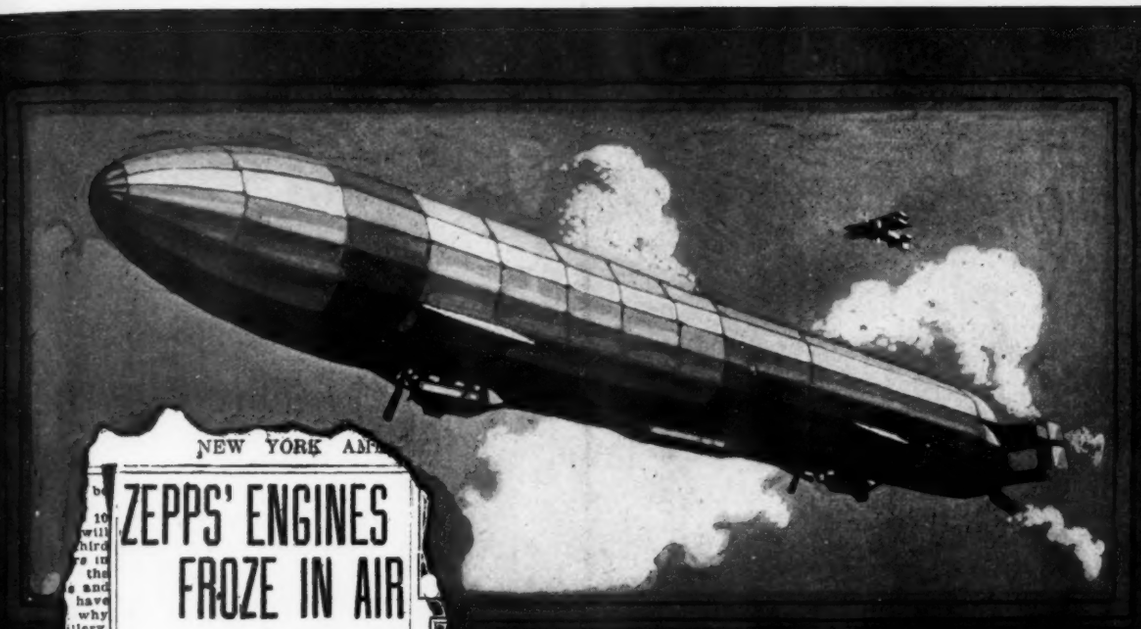

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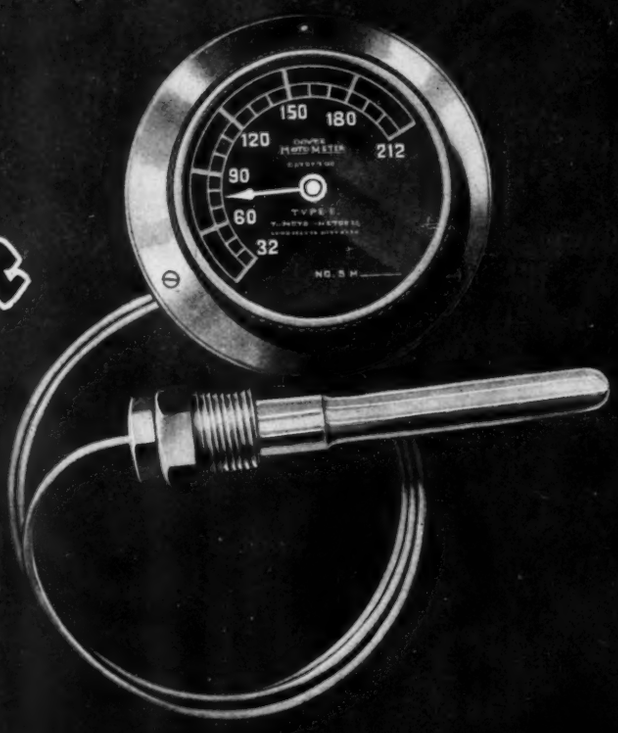

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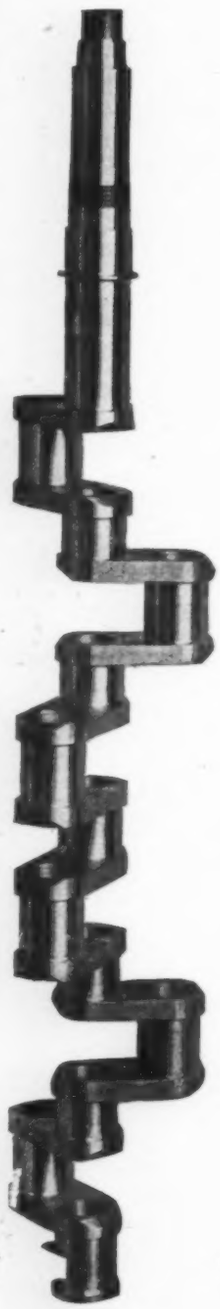

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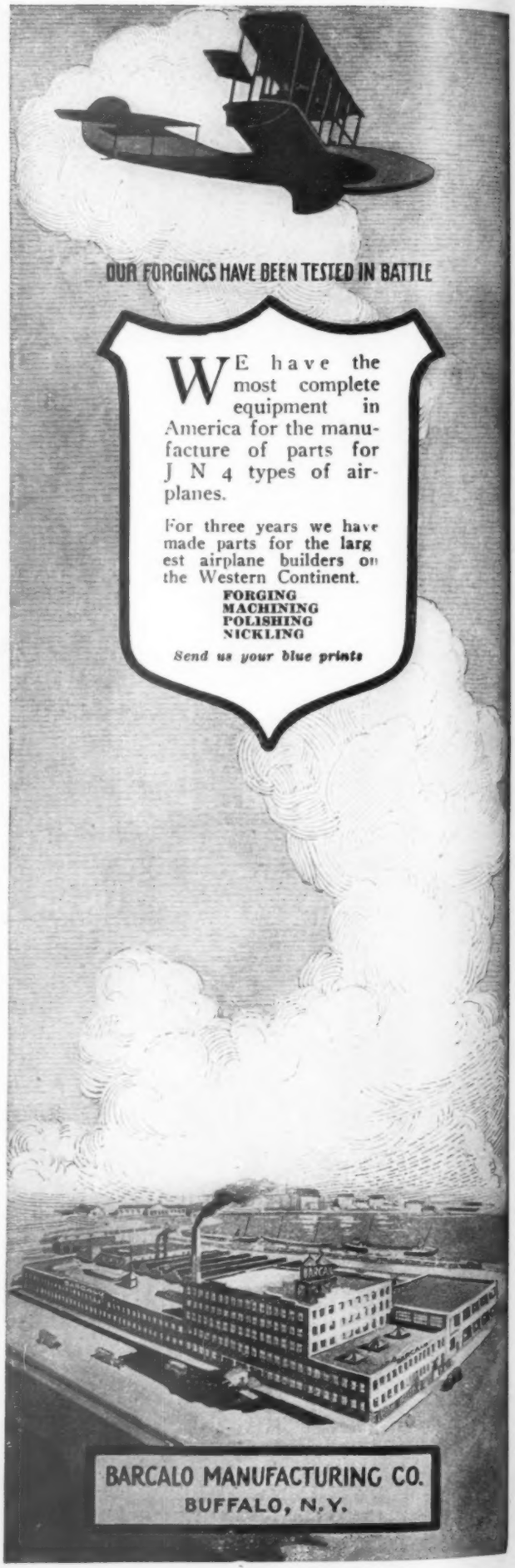
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Vol. IV | March 1, 1918 | No. 3

Location of Seaplane Floats

By R. N. Wing, M.E.

Curtiss Aeroplane and Motor Corporation

Airplane design has reached the stage where it is essential to eliminate all unnecessary shop work, and practically all parts can now be properly located before the construction of a machine is begun. A method for determining the correct location of the main floats on a seaplane is herewith explained.

A seaplane is practically a land machine so altered that it can maneuver on, rise from, and alight upon the water instead of the land.

Large machines have two main floats or pontoons, while small machines usually have only one main float located directly under the body and two wing pontoons located under the lower wings at the outer wing posts to prevent the machine from tipping over sideways.

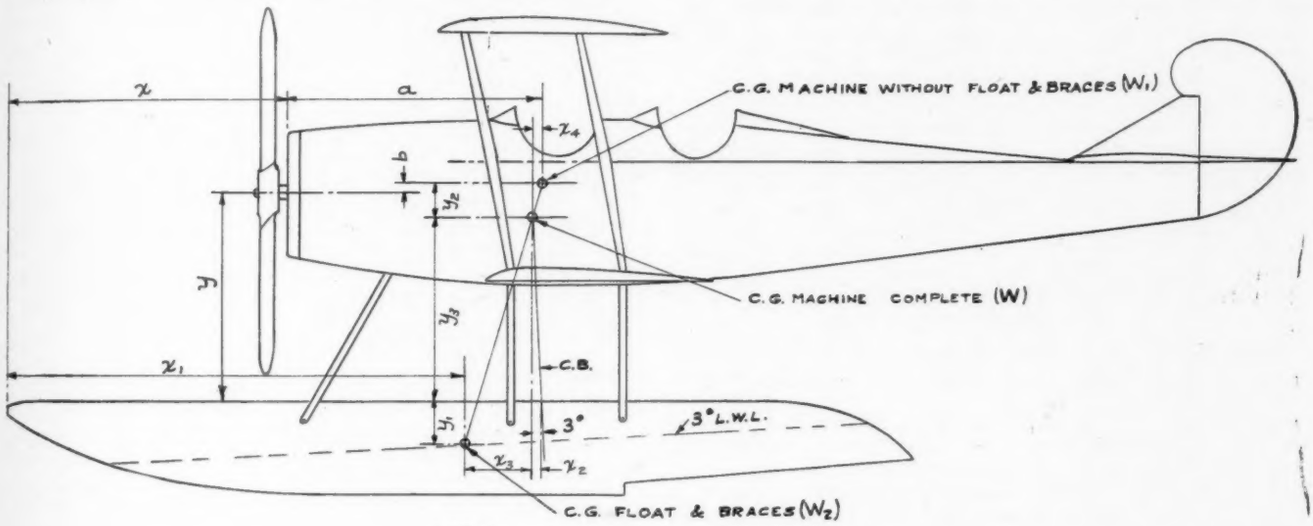
Floats are usually designed to have a total displacement of 200 per cent of the total weight of the machine including the floats, while on small scout hydros 50 to 60 per cent excess buoyancy is sufficient.

It is good practice to have the top of the main float parallel to the propeller axis, and to so locate the float with regard to the fore and aft position that the machine will rest on the water inclined at about 3° to the water level, or in other words, "3° down by the tail." This is to prevent the machine from nosing over on starting up on the water, due to the diving moment caused by the propeller thrust and the resistance of the float in the water. Of course, no matter where the float is located, when the machine is in equilibrium, resting on the water, the vertical through the center of buoyancy of the displaced water will pass through the center of gravity of the complete machine. As the angle of inclination of the float is increased, the excess buoyancy at the rear end of the float decreases. The float may therefore be located too far forward, with the result that a gust of wind will tip the machine back on its tail.

The method for locating floats is the same whether single or twin floats are used, so we will consider the case of a single main float. The procedure may be divided into five steps as follows:

1. Determination of the weight and center of gravity of the machine with full load excepting the main float and float bracing.
2. Estimation of the weight of the float and bracing, and the resulting full load weight of the complete machine.
3. Design of the float for the required buoyancy and the calculation of the 3° load water line and the center of buoyancy line for the full load weight.
4. Determination of the vertical position of the float with regard to the rest of the machine.
5. Determination of the horizontal or fore and aft position of the float.

These steps will now be taken up in order and briefly discussed.



LOCATION OF SEAPLANE FLOATS

1. Weight and Center of Gravity of Machine Without Float and Bracing

We can either estimate these quite closely, or if we already have an airplane which we wish to operate on the water, we can obtain its actual weight and center of gravity by weighing it on two sets of platform scales, firstly in a horizontal position, and secondly in an inclined position with the tail down. The intersection of the verticals through the center of gravity in both positions will determine the location of the center of gravity both the horizontal and vertical co-ordinates. In either position if we let "L" represent the distance between the two supports or scales, "F" the net weight on the front scales and "R" the net weight on the rear scales, then the vertical through the center of gravity is at a distance equal to $\frac{RL}{F+R}$ aft of the front support.

Measurements of the points of support should be made very carefully and be referred to some fixed point on the machine,

for upon these measurements depends the accuracy of the result. If the machine is weighed with the original landing gear on it, this weight should be deducted and any weights which were not included, such as fuel, etc., should be added and corrections made in the center of gravity.

II. Weight of Float and Bracing, and Full Load Weight of Complete Machine

The weight of the main float and bracing can be estimated at about 15 per cent of the weight of the rest of the machine, or the full load weight of the machine complete will be about 1.15 times that of the machine without float and bracing.

III. Design of Float

The approximate full load weight of the complete machine (W) having been estimated, the required buoyancy is $2W$ pounds, or the total volume of the float should be $\frac{2W}{62.5}$ cubic feet.

After the float has been designed, the 3° load water line is determined by first drawing a line at 3° to the top of float on the side elevation of the lines drawing, which will approximately divide it into two equal volumes. The actual displacement below this line is then carefuly calculated by means of Simpson's rule, and the 3° L. W. L. is corrected. The center of buoyancy or displacement is next determined by taking moments of the various small volumes below this 3° L. W. L. about some fixed point, and then dividing the sum of these moments by the sum of volumes or displacement. A line is then drawn through this center of buoyancy perpendicular to the 3° L. W. L. and the point where this line cuts the top of the float is noted.

IV. Vertical Position of Float

The vertical position of the float can be readily decided upon by allowing 6″ clearance between the top of float and the lowest point of the propeller tip travel, so that the propeller will easily clear the float and will not strike much of the spray from the float. It is often well to have small fins, or splash plates, fastened onto the float near the front to deflect the spray downward and away from the propeller.

V. Horizontal Position of Float

The remaining data which are needed for the determination of this position are the actual weight and center of gravity of the combined float and braces.

A good designer can closely calculate the weight and center of gravity of the float itself from his construction drawings, or better still, after the float is constructed, its actual weight and center of gravity can be obtained accurately by the "suspension and displacement" method described in the Oct. 15, 1917 issue of AVIATION AND AERONAUTICAL ENGINEERING, page 381.

It is now necessary to determine the approximate location of the bracing from the float to the body, so that its weight and center of gravity may be calculated. For this purpose we may temporarily assume that the center of buoyancy line passes about 2 or 3″ ahead of the previously determined C. G. of the machine without float and braces. The weights of the float and the braces can now be added and their combined center of gravity be referred to the float.

Knowing the vertical co-ordinates of the centers of gravity of the machine without float and braces W_1 and of the float and braces W_2, and the vertical distance "1" between these co-ordinates, we can calculate the vertical co-ordinate of the C. G., of the machine complete with float and braces W by the equation $y_2 = \frac{W_2 1}{W_1 + W_2} = \frac{W_2 1}{W}$ below the C. G. of machine without float and braces.

Now draw four parallel lines at the correct distances apart to some convenient scale, say 3 in. = 1 ft. 0 in., to represent the vertical co-ordinates of the center of gravity of the machine with and without the float and braces, the C. G. of the float and braces, and the top of the float. Next assume any convenient point on the line representing the vertical co-ordinate of the C. G. of the complete machine W, as the horizontal position of its C. G., and draw a line down from this point at 3° aft of the vertical. Where this 3° line cuts the horizontal representing the top of float, will determine the position of the center of buoyancy of the float. The center of gravity of the float and braces W_2 is already known with respect to the center of buoyancy of the float, so it merely remains to draw a straight line through this C. G. and the C. G. of the complete machine and produce it until it cuts the horizontal line representing the vertical co-ordinate of the machine without float and braces W_1. This will determine the position of the C. G. of the machine without float and braces, and we now have located the horizontal position of the float with regard to the fuselage.

If a person does not wish to draw up this work to scale, it can be figured mathematically as follows:

The distance along the top of float from the vertical through the C. G. of complete machine to the center of buoyancy line $X_2 =$ tan 3° x y_3 where y_3 is the vertical distance from top of float to C. G. of complete machine.

The horizontal distance X_3 from the C. G. of float and braces to the vertical through C. G. of complete machine is equal to the horizontal distance from C. G. of float and braces to point where center of buoyancy cuts top of float, tan 3° x y_3.

Then the horizontal distance of the C. G. of machine without float and braces W_1 aft of the vertical through C. G. of complete machine is $X_4 = \frac{X_3 \times y_2}{y_3}$

An example will make this method clearer.

VI. Data and Calculations

1. Full load weight of seaplane including men, fuel, etc., but without landing gear W_1 =1900 lb., and its center of gravity is located $a = 66$ ft. aft of face of radiator and $b = 2$ in. above line of propeller axis or thrust.
Propeller has an outside diameter $d = 8$ ft. 0 in.

2. Estimated weight of float and braces $W_2 = .15 \times 1900 =$ 285 lb. say 250 lb. for float and 35 lb. for braces.
Estimated full load weight of machine complete with float and braces $W = W_1 + W_2 = 1900 + 285 = 2185$ lb.
Required buoyancy of float $= 2 \times 2185 = 4370$ lb. or 70 cu. ft.

3. Float assumed 20 ft. 0 in. long, 32 in. wide and 24 in. deep with rounded top. The 3° L.W.L. for 2185 lb. and center of buoyancy or displacement are assumed to be as shown on sketch, the point where the latter cuts the top of the float being 2 ft. 0 in. aft of the amidship section or 12 ft. 0 in. aft of nose of float.

4. Clearance of propeller over top of float $c = 6$ ft. Top of float below propeller axis $y = \frac{d}{2} + c = 4$ ft. 0 in. $+ 6$ ft. $= 4$ ft. 6 in.

5. Weight of float = 250 lb., and its center of gravity is 10 ft. 3 in. aft of nose and 15 ft. below top. Weight of float braces = 35 lb. and their center of gravity is 11 ft. 8 in. aft of nose and 14 in. above top of float. Weight of float and braces $W_3 = 285$ lb. and their combined center of gravity is $X_1 = \frac{250 \times 123 + 35 \times 140}{285} = 125$ in. $= 10$ ft. 5 in. aft of the nose and $y_1 = \frac{250 \times 15 - 35 \times 14}{285} = 11.45$ in. below top of float.

Horizontal distance from intersection of center of buoyancy and top of float to center of gravity of float and braces = 12 ft. 0 in. $-$ 10 ft. 5 in. $= 19$ in.

Vertical distance from center of gravity of float and braces to center of gravity of machine without float and braces $l = b + \frac{d}{2} + c + y_1 = 2 + 48 + 6 + 11.45 = 67.45$ in.

Vertical distance of center of gravity of machine complete below center of gravity of machine without float and braces $y_2 = \frac{285 \times 67.45}{2185} = 8.8$ in.

Center of gravity of machine complete above top of float $y_3 = c + \frac{d}{2} + b - y_2 = 56 - 8.8 = 47.2$ in.

$X_2 = y_3 \times \tan 3° = 47.2 \times .0524 = 2.475$ in.

$X_3 = 19 - x_2 = 19 - 2.475$ in. $= 16.525$ in.

$X_4 = \frac{y_2 \times X_3}{y_1 + y_2} = \frac{8.8 \times 16.525}{11.45 + 47.2} = \frac{145.2}{58.65} = 2.48$ in.

The nose of float should be $X_1 + X_3 + X_4 = 10$ ft. 5 in. $+ 16.52$ in. $+ 2.48$ in. $= 12$ ft. 0 in. ahead of C. G. of machine without float and braces, or the face of radiator should be 12 ft. 0 in. $- a = 12$ ft. 0 in. $- 5$ ft. 6 in. $= 6$ ft. 6 in. aft of nose of float.

The correct position of float is now located, top of float 4 ft. 6 in. below propeller axis and nose of float 6 ft. 6 in. ahead of face of radiator.

The Mathematics of Aerodynamics*

By Edwin Bidwell Wilson

Professor of Mathematical Physics, Massachusetts Institute of Technology

In the development of a branch of engineering there are several stages, sometimes long drawn out and poorly differentiated, sometimes brief and sharply defined.

There is the stage in which the bold inventors, trying one way and another, often with personal danger or even disaster, accomplish the first crude beginnings. In ship construction this epoch is prehistoric; in steam engineering it starts, at least in story, with Watts; in electrical engineering it lies within the memory of men still living; in aeronautics it stretches over a long period admirably described by A. F. Zahm in his book "Aerial Navigation." The first essays in aeronautics, if we overlook the legendary Icarus, were with the balloon and the balloon-type machine; progress with the heavier-than-air type may well be dated from Langley and the Wrights, though experiments with gliders are known for some time previous to them.

There is another stage—that in which the properly equipped mathematician and physicist construct a theory to correspond to the branch of engineering and by the indications of that theory aid materially in hastening the development of improved types of machines, or at least, if they arrive too late to help in the major development, they assist in codifying the fundamental scientific principles which underlie the subject and make possible systematic training of the youth to carry on the advance in details.

The development of mathematics and physics was sufficient before the advent of electrical engineering to enable major advances to be made by William Thomson (later Lord Kelvin), by Oliver Heaviside, and by M. I. Pupin, to mention only three. In the case of the simpler parts of mechanical engineering and of naval architecture, the pressing necessities of prehistoric and early historic man were such that the art far outstripped the science; indeed the limitations of our mathematical and physical knowledge of the behavior of liquids are still so serious that when we wish a cup-defender we have to rely almost entirely upon the fine sense of a genius like Herreshoff instead of upon the theories and calculations of engineers like Prof. C. H. Peabody and Rear Admiral Taylor.

In the development of the airplane, however, since the early experimental and inventive successes of the Wrights and their competitors and followers in France, much has been accomplished in a single decade by the mathematician and physicist, in particular by G. H. Bryan, whose book "Stability in Aviation" was epochal, and by L. Bairstow of the National Physical Laboratory, Paddington, England, whose experimental and theoretical work has done so much toward rendering Bryan's ideas directly and surely applicable to actual flying machines. I have been fortunate enough under commission from our government to add my mite to the theoretical advance ("Motion of an Airplane in Gusts"), and we in this country should all do much homage to the pioneer work which Lieut. J. C. Hunsaker, U. S. N., performed at the Massachusetts Institute of Technology.

There is a third stage, a relatively late stage in this uprearing of a branch of engineering. Here we find the scientific and technical knowledge so codified in text-books and manuals that it is not particularly hard for a school of technology, properly equipped with laboratories and teaching staff, to take in as raw material average young fellows and turn out as manufactured product tolerably competent engineers, able to design and make minor improvements in standard machines.

This stage is not yet quite attained in aeronautics, but with the obviously great technical advances which have come about with such perplexing rapidity during the past two or three years under the pressure of war necessities in Europe and in this country, and with the presumably great theoretical advances which have accompanied them, it certainly will not take long after the war shall have terminated and after the present belligerent governments shall have ventured to divulge the ways and means and ends in aeronautics which they now guard so sedulously—it certainly will not then take long to work down the science and art of aeronautical engineering to the point where it takes its place in this third stage with mechanical, civil, and electrical engineering.

Already a preliminary codification may be found in the course prepared by Messrs. Klemin and Huff, on the basis of the course given by their former teacher Dr. Hunsaker.

My subject is the Mathematics of Aerodynamics, and if I have been long in my preamble it is merely because I feel that before we examine one special phase of aeronautics, the phase that interests us here most nearly, we should first take a broad view of the whole field to acquire the perspective necessary for a just appraisal of the value and of the limitations of mathematics in engineering.

Mathematicians as investigators are concerned chiefly with but a single stage of the work. They cannot aid much in the first hardy adventures; they cannot help greatly in the final codification—except as they strive as teachers better to prepare the Freshman and Sophomore in his mathematical courses for the technical work to which he looks forward; they can help materially in the intermediate stage, provided they have schooled themselves in that style of mathematics which is suited to the treatment of engineering problems, that is in mechanics and mathematical physics.

In discussing aeronautical machines mathematically, or otherwise, a sharp distinction must be made between the lighter-than-air and the heavier-than-air types—the balloon and the plane types, as we may briefly designate them.

For the balloon type the first mathematical work will naturally be very elementary, dealing with buoyancy, with the expansion and contraction of gases owing to rise and fall in the level of flight and to changes of temperature. Arithmetic and algebra alone or the simplest portions of the calculus will suffice. If the coefficients of resistance to motion are known or assumed for different shapes of balloon, simple calculations will determine the power necessary for uniform rectilinear motion. As resistances are supposed to vary with some power, generally the square, of the velocity, easy problems in the calculus may be made regarding stopping and starting with no further use of differential equations than the "variables separable" type.

In discussing the airplane some small use of trigonometry is necessary. The pressure P in a plane surface of area S, which is taken as a first approximation to a wing, is assumed to be normal to the plane (the viscous tangential drag being neglected), and of the form $P = kSv^2 \sin i$, where i is the angle between the wing and the direction of motion. This is resolved vertically and horizontally to give the "lift" L and "drift" D as

$$L = kSv^2 \sin i \cos i, \qquad D = kSv^2 \sin^2 i.$$

In uniform horizontal flight $L = W$, the weight of the machine, and $D = F$, the thrust of the propeller. (To a first approximation the resistance of all surfaces other than the main wing of the monoplane or the pair of wings of the biplane are neglected.) The power necessary to drive the wing through the air is then nearly.

$$\frac{Dv}{550} = \frac{W^2}{550\ kSv}$$

This shows that for a given machine, the power is inversely as the velocity. The apparent anomaly is explicable by virtue of the fact that at higher velocities the machine flies at smaller angles of incidence i. A pretty exercise may be had by assuming that the resistance other than that due to the wings may be lumped together in a term Cv^2 added to the drift D so that the power becomes

$$\frac{W^2}{550\ kSv} + \frac{Cv^3}{550};$$

the minimum power may then be determined with its corresponding speed; and the further result that for the speed which minimizes the power, the weight per horsepower varies inversely as the speed.

There are a number of such simple applications of trigonometry and calculus which may be introduced in many a course in mathematics for the purpose of enlivening the work. One particularly interesting calculation is found by contrasting the expression for the power which has been obtained from the assumption (known to Euler) that the pressure varies with

* Read before the Mathematical Association of America.

the sine of i with the expression which would be obtained from the erroneous assumption (generally attributed to Newton) that the pressure varies with the square of the sine of i. Those of you who are interested in the application of elementary mathematics to the airplane will find a great deal of suggestion in Painlevé and Borel's "L'Aviation."

I wish next to mention those parts of advanced mathematics which are used by writers on aerodynamics. Beginning with Kirchhoff and Lord Rayleigh and reaching its culmination in recent work by Sir George Greenhill, the theory of functions of a complex variable has been indispensable in deriving theoretical formulas for the pressure P of a stream of air on a wing.

Problems in hydrodynamics which take account of eddy (or vertical) motion or of internal friction (viscosity) are so difficult to solve that one may with reasonable accuracy say that for theoretical work in aerodynamics, eddies and friction must be disregarded; and for similar reasons the fluid motion is ordinarily restricted to plane motion. There are to be sure "end-effects" when a wing moves through the air, but owing to the length of span an approximation of value may be had by neglecting the "end-effects" and assuming that the motion of the air in all planes perpendicular to the edge of the wing is identical. Now by the method of "conformal representation" of the theory of functions the pressure exerted in a plane wing of various shapes, by the motion of the air may in some cases be calculated, and the center of pressure may also be found.

These theoretical determinations of pressure and center of pressure are not precisely verified when experimentally measured in the wind tunnel and it is now customary to use the experimental values in place of those theoretically calculated. Nevertheless no student of theoretical aerodynamics can afford to be ignorant of the elements of hydrodynamics including the theory of the reactions of streams on given contours, and this means that he must have some knowledge of the theory of functions of a complex variable, or rather let me say, some knowledge of the means of applying the principle of conformal mapping to the setting up of the functions which gives the map of one boundary and enclosed region upon another boundary and enclosed region.

It is unhappily true that many extended and beautiful courses on the theory of functions leave the student wholly unable to carry through the applications necessary to the solution of these practical, or at least semi-practical, problems in hydromechanics. Might I suggest to all who teach the complex variable and the conformal map the possibility of drawing on uniplanar fluids motion as a source of instructive exercises?

Owing partly to the divergence between theory and experiment in fluid motion in simple cases and partly to the impossibility of obtaining a theoretical hydrodynamic solution for the motion of so complicated an object as an airship or airplane, it is necessary in the main to treat the ship or plane as a rigid body to which are applied certain forces (resultant fluid pressures and moments of pressures) determined by wind tunnel experiments upon models. The problem of the motion of the machine then becomes one in the dynamics of a rigid body free to move in space (i. e. with six degrees of freedom) subject to known forces. It is customary to refer the motion to axes fixed in the machine and moving with it. Now unfortunately moving axes are regarded as belonging to really advanced rigid dynamics. Routh in his two volumes "Elemenary and Advanced Rigid Mechanics," leaves moving axes to the beginning of the Advanced Part. Single volume treatises such as Loney's "Dynamics of a Particle and of Rigid Bodies" are apt to stop before reaching moving axes.

It is not at all unlikely that the present interest in the dynamics of flight will force us so to alter our texts and our courses as to include the theory of moving axes; for we cannot expect students to prolong their studies of mechanics unduly before entering upon the motion of aerial machines.

Whether referred to moving or fixed axes the equations of motion of an airplane or airship, with the forces represented by empirical equations experimentally determined, are too difficult to integrate without approximation. The first case treated is that of motion in a line nearly straight and inclined to the horizontal at a nearly constant angle. By considering the motion as made up of small departures from uniform flight in straight lines, the differential equations of the motion become linear equations with constant coefficients, and their solution is therefore a matter of well known, though sometimes very tedious, routine. And right here allow me to intercalate the remark that we must not ourselves disdain arithmetic nor allow our students to be discouraged by it; there is current all too much of a feeling that only the beautiful general theories of mathematics are worthy the attention of real mathematicians and their students; the art and the science of getting a sufficiently accurate numerical solution of a numerical problem are of equal importance and dignity with general theory in all applications of mathematics.

The utility of the solution of the nearly uniform motion of the machine is found in the discussion of dynamical stability. The approximate equations are solved, as all linear equations with constant coefficients, are solved, in terms of exponential functions with or without combination with trigonometric terms.

If a machine dynamically stable is slightly disturbed from uniform motion the small departures from that standard state will die out as time goes on, i. e. the exponential functions must have negative exponents like e^{-at}. It is a pretty and none too easy algebraic problem, solved in Routh's "Rigid Dynamics" but not in many books on algebra, to determine the conditions under which an algebraic equation has its real roots, and the real parts of its imaginary roots, negative. The practical importance of dynamical stability in a machine is that under normal atmospheric conditions and for short periods of time the machine may safely be flown "hands off" and the pilot has therefore more freedom to attend to other matters than the guiding of his craft.

I have been told that the theory of Bryan, recast by Bairstow, and supplemented by data of wind tunnel experiments has enabled a machine to be designed and constructed which actually has been flown "hands off." If this be true it marks a great triumph for mathematical physics; whether it is true or not, we can confidently assert that to the English training in mathematical physics is in no small degree due the great and sudden advance in airplane design and the great success in aircraft warfare which have been realized in England in relatively few months.

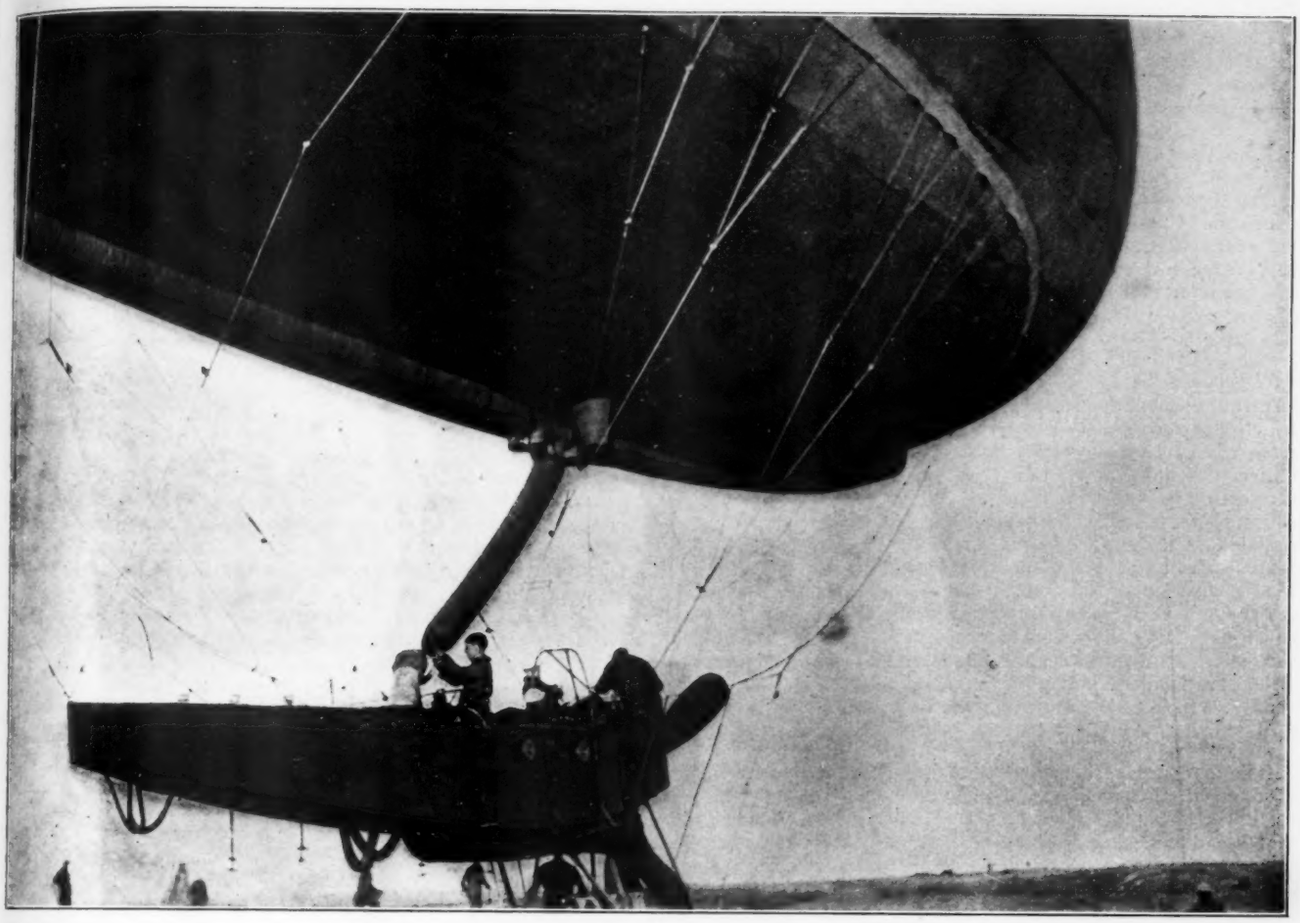
I have shown you that the mathematics of aerodynamics leads from elementary algebra and arithmetic to the theory of functions of a complex variable and to the solution of linear differential equations with constant coefficients. I have shown how the theoretical work has come in that stage of the development of aeronautical engineering where it has been of real help in rapidly advancing the art. There are always with us branches of engineering and physics in which the right kind of mathematics is of great value for the rapid advance of those branches. This right kind of mathematics is the good old traditional Cambridge, England, type, the mathematics of Newton, of Green, of Maxwell, of Kelvin, of Rayleigh, a type of mathematics which in this country, owing perhaps to our preponderance of German trained mathematicians, has all too little prestige.

I sometimes wonder whether we do right to aim so exclusively at the continental type. It is worthy of note that our two great native mathematicians, George W. Hill and J. Willard Gibbs, were concerned with the applied side. May it not be that we in this country have such a natural bent toward the practical that a diligent cultivation of the British sort of mathematics would find a readier response among our students?

We are here not as research mathematicians but as teachers of collegiate mathematics. Our country has great industrial problems of peace and war to solve, and every one of us must help as he may. As we bend the mathematical twig, so will the tree incline. Let us without prejudice consider our curricula and with open mind introduce any necessary changes to make sure that the type of mathematics which we place before our students is that which will contribute most to the victory of our country in time of stress and to her prosperity in times of peace.

Senate Confirms Aircraft Board Nominations

The President's nominations of Howard E. Coffin, chairman, and Richard F. Howe, member, of the Aircraft Board, were confirmed by the Senate on Feb. 14. The Army and Navy each are represented by three officers, and there still remains one civilian to be appointed by the President.



A Submarine Scout Airship of the United States Navy

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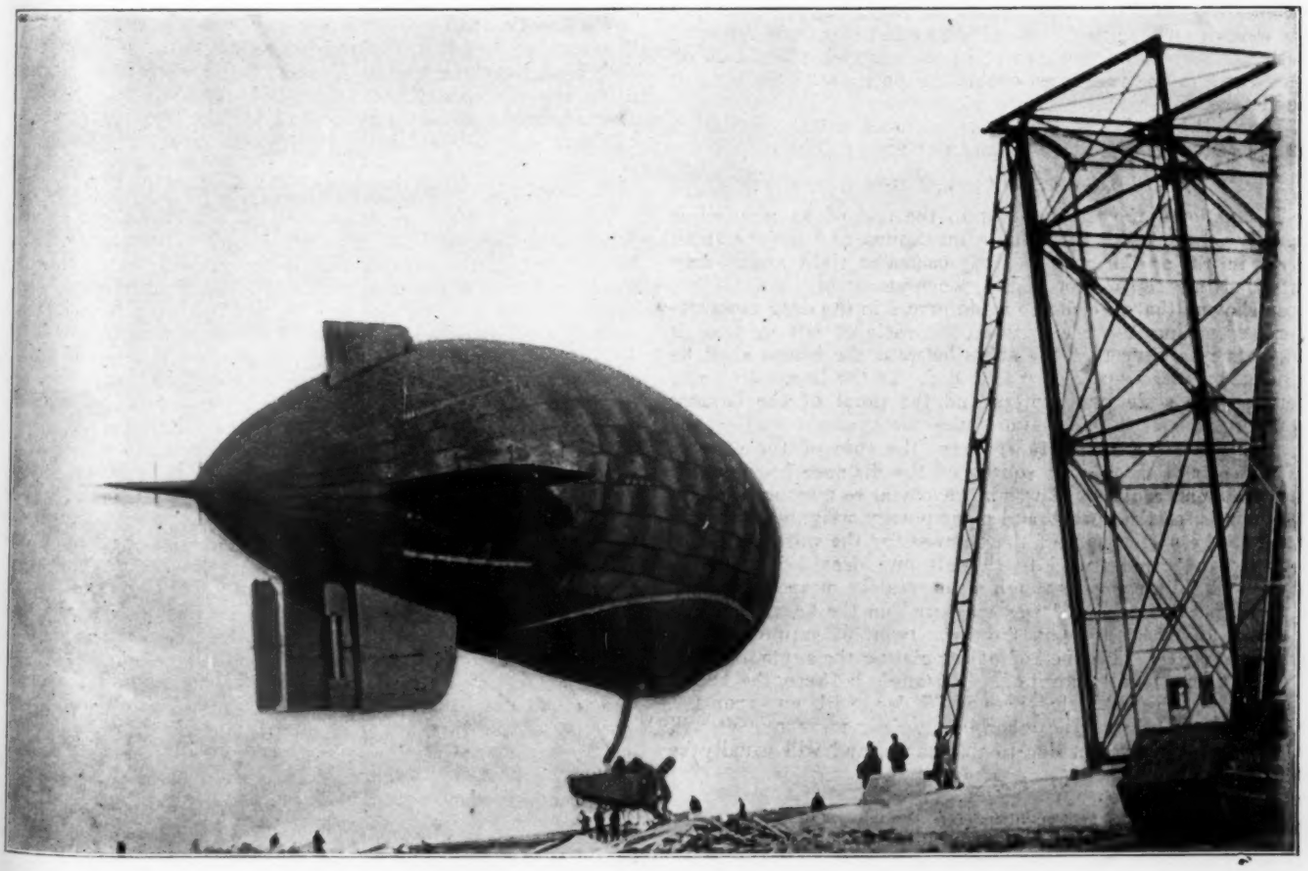


The Wind Channel: Its Design and Use

By J. A. Parnell, A.F.Ae.S.

(Concluded from last issue)

*Erecting the Main Balance**

In order that certain conditions essential for accurate working shall be fulfilled, it is necessary that the erection of the balance be carried out with considerable care. The methods which are used for this purpose and to check the accuracy of workmanship will now be described.

Vertical Axis of Rotation in Moment Measurements

When the balance is arranged for the measurement of moments about a vertical axis the strut which prevents motion about this axis when lift and drag are being measured is removed, and the lower extremity of the balance engages a center, the position of which, in conjunction with the main supporting point of the balance, fixes the axis of rotation. The position of this lower center is adjusted till the axis of the balance is vertical, when hanging weights on the lift and drag beams produce no moment about the axis of rotation. The sensitivity of the moments measuring apparatus renders the method easily accurate to an inclination of the axis of 0.005 deg. The axis of rotation in the N.P.L. channels is vertical to an accuracy of about 0.03 deg. The clamp which locks the balance should be arranged to hold it in approximately the same position when the lower center is not in use.

Position of Axis of Rotation of Upper Part of Balance

It is a matter of considerable convenience in measurements of moment about a vertical axis if the axis of rotation in changing the angle of incidence of the model coincides with that about which moments are measured. The relative positions of these two axes can be determined by fixing a point to the upper portion of the balance, adjusting it to lie in the axis of rotation of the upper portion, and then hanging from it a weight. If the balance remains in equilibrium when supported on a single point, the axis under examination is vertical, and therefore in coincidence with that about which moments are measured. If the balance turns under the weight, it must be returned to its zero position by changing the weights on the lift and drag beams and the process repeated with the point at a new height in the channel. Readings of the beams in the two cases enable the position of the axis to be determined.

The N.P.L. balances have been adjusted till the deviation at the center of the channel does not exceed 0.01 in.

Angle Between the Lift and Drag Beams

The ratio of the lift to drag in the test of an aerofoil is usually of the order of 17 as a maximum, and a very small error in setting the lift and drag beams at right angles may introduce a serious error in the measurement of drag. It has been shown† that in order to avoid errors in the drag measurement exceeding 1 per cent when the ratio of lift to drag is 15, it is necessary that the angle between the beams shall be 90 deg. to an accuracy of + 0.05 deg. If the linear distances between the scale pan centers and the point of the balance can be accurately determined, the most direct method of measuring this angle is to compare the sum of the squares of these lengths with the square of the distance between the two scale pan centers. It was inconvenient to measure directly the lengths of the beams, and a temporary weighing arm was fixed to the upper part of the balance for the purpose. This was set in turn parallel to the lift and drag beams and a weight of 1 lb. moved through an accurately measured length. The moment thus caused was measured on the beams and the distance of each scale pan from the point of support of the balance deduced. The method of calculating the angle, referred to above, can now be applied. The angle between the beams in each of the N.P.L. balances is 90 deg. with an error not exceeding 0.02 deg. The error in the drag measurement will not exceed ½ per cent due to this cause, and will usually be much less.

* See Report Advisory Committee for Aeronautics, 1912-13, p. 50.

† Rept. Advisory Committee for Aeronautics, 1912-13, p. 63.

Determination of Wind Direction and Its Relation to the Position of Beams

The accuracy with which it is necessary to set the beams along and across the wind direction is the same as that with which the angle between the beams is required to be a right angle. An error in the two cases has the same result—viz., to include a component of the lift in the drag measurement.

The wind direction has been found to be parallel to the walls of the channel to an accuracy of 0.1 deg., but it is determined by the experiment which gives the angle between it and the drag beam.

The method which has been used for this determination is to mount an aerofoil in the balance, with its span vertical, and measure the lift and drag over the usual range of angle. The model is then rotated through 180 deg. about the wind direction (thus reversing the direction of the lift) and a second set of measurements taken. The mean of the two sets gives the true value of the faces, and their difference enables the errors of wind direction and balance setting to be determined.

An actual set of observations which was obtained in calibrating of the channels now follows. The two lift curves differed by an angle of 0.2 deg., the datum line to which the aerofoil was set being half this amount in error from the true wind direction. The drag curves, however, could not be made to agree by movement of one of them along the abscissæ; the difference being due to the drag beam not being set along the wind direction. As would be expected, since the difference in the drag curves was due to a component of the lift, the two drag curves crossed at the angle of zero lift. The angle error can be estimated by moving one curve along the angle base by the amount indicated by the lift curves (0.2 deg.) and reading off the drag from each curve at several angles. If L is the lift at any angle and α the angle between the beam and the wind direction, then half the difference is equal to $L \sin \alpha$, and α can be deduced. In this case α was equal to 0.16 deg. The balance was turned through this angle by adjusting the length of the "torque stop," and the experiments repeated, using the wind direction indicated by the lift curves. The forces should now be in agreement for the two presentations of the model.

Measurement of Wind Velocity

A pitot and static pressure tube of the type used by Dr. Stanton was adopted for measurement of wind velocity. The head in use at the present time is the same in principle, but has been arranged somewhat differently for convenience. This type of head has been tested on the whirling arm at the Laboratory,‡ and the difference of pressure was found to be $\frac{1}{2}\zeta V^2$, while that in the static pressure tube was equal to the pressure of the undisturbed air in the building. The accuracy was limited by that of the test, which was of the order of 0.1 per cent on the velocity.

It was at first hoped to measure the velocity in the channel during a test by mounting this head some 3 ft. (100 diameters of the vertical tube of the head) upstream of the model. This plan was abandoned, as it was found that there was a region in the neighborhood of the balance about 1½ in. wide in which the velocity was 10 per cent below the mean. The alternative method which was adopted consisted in measuring the pressure difference between a hole in the side of the channel and the free air in the room. In order that the pressure in this hole may not be changed by the presence of the model, it should be located sufficiently far upwind of the balance to be in front of the model. The pressure difference is greater than $\frac{1}{2}\zeta V^2$, on account of the pressure drop in passing the honeycomb and early part of the channel. The pressure difference, however, varies, as V^2 and the channel is readily calibrated by placing the standard anemometer over the balance. This calibration

‡ "Engineering," Sept. 12, 1913.

can be made with an accuracy of about 1 per cent on V^2, and should be repeated at stated intervals. The pressure difference is measured on a Mattock tilting manometer, which has been fully described elsewhere.*

The Mattock manometer is in general use at the N.P.L., but it suffers from one defect which is not present with the inclined tube type of gage. It is necessary that the Mattock manometer shall have continuous attention during the time it is in use, and in the case of a failure of the electric supply the observer can seldom shut the tap before the surface is ruptured. It is then usually several minutes before the gage can be used again, and it is liable to change of zero for a longer period.

Experiments have been carried out at Massachusetts Institute of Technology, U. S. A., with the "Krell" type of inclined tube manometer,† and the conclusion arrived at was that if properly constructed and used the gage could be regarded as an instrument of precision suitable for wind channel work. It requires calibration, and may be compared with a Mattock manometer which is an absolute standard. The inclined tube gage appears to be sufficiently accurate for use on a channel where the fluctuations usually limit the accuracy attainable. It cannot be too strongly stated that a steady electrical supply is a matter of the highest importance if accurate results are required. In the writer's opinion there is no doubt whatever that, with channels of the type in use at the N. P. L. and with the usual conditions of electrical supply, the accuracy of the observations depends entirely on the steadiness of the wind speed. If a channel which normally works on the ordinary supply circuits is connected to a storage battery, the improvement in the accuracy of the experiments and the reduction in the time taken is most marked. If a storage battery cannot be provided, a Tirrell regulator makes a fairly efficient substitute. The author has had no experience of automatic speed regulators; the only one of which he has seen a description (in use on the channel at Göttingen) is operated by the pressure difference on either side of the fan. In order to avoid "hunting," it appears that it would be preferable to adopt a device (possibly operated by centrifugal force) which would regulate directly on the speed of the airscrew, since the variations here are presumably the source of speed variations in the channel.

Comparison of the Channels

The differences between the 3-ft., No. 1 4-ft., and No. 2 4-ft. channels are small, and confined to improvements in the convenience of working in favor of the latter. The woodwork of the two 4-ft. channels is the same, and though no comparative measurements of steadiness have been made, there appears to be little to choose between the two. The maximum speed of the No. 2 4-ft. is 80 ft. per sec., while that of the No. 1 4-ft. is 50 ft. per sec.

The No. 2 7-ft. channel is not an exact copy of the No. 1. The buildings in which they are housed are of approximately the same size, but as the newer channel is supported on steel frames instead of concrete columns, the obstruction to the flow of air returning to the intake of the channel is appreciably less.

The overall dimension is 86 ft. in each case, but the two channels differ in the manner shown in the following table of approximate values:

	No. 1, 7 ft.	No. 2, 7 ft.	No. 1, 4 ft.	No. 2, 4 ft
Overall length	..	..	52 ft.	52 ft.
Length of parallel portion	41 ft.	41 ft.	25 ft.	25 ft.
Intake to balance	20 ft.	25 ft.	6 ft.	6 ft.
Length of distributor	35 ft.	32 ft.	21½ ft.	4 ft.
Length of core to propeller	10 ft.	13½ ft.	4 ft.	21½ ft.
Angle of cone (internal)	20°	20°	30°	30°
Diameter of propeller	10 ft.	11.5	5½ ft.	5½ ft.
Effective pitch diameter ‡	0.50	0.7	0.60	0.75
R.p.m. at 60 ft. per sec.	1000	910	(50 ft. per sec.) 1350	1300
Power absorbed at 62 ft. per sec.	48 hp.	56 hp.	(50 ft. per sec.) 8 hp.	14.6 hp.
R.p.m. at 80 ft. per sec.	..	1210	..	1500
Power absorbed at 80 ft. per sec.	..	155 hp.	..	(70 ft. per sec.) 23.3 hp.

* Report Advisory Committee for Aeronautics, 1912-13, p. 35.

† Smithsonian Misc. Col., Vol. 62, No. 4, p. 34.

‡ Effective pitch is calculated from airspeed in the channel just before the airscrew (neglecting increase of velocity due to inflow) divided by r.p.m.

The No. 2 7-ft. channel has been found to be less steady than the No. 1 7-ft., in spite of the increased area available for the returning air. The difference is possibly due to the increase in the pitch of the propeller, and possible also to the reduced length of the distributor.

A few particulars of the cost of erecting the wind channels may be of interest. The figures given were estimated to cover replacement under present conditions in the event of loss by fire, and are based on the actual cost of erection under the supervision of H. M. Office of Works:

	No. 2, 7 ft.	No. 2, 4 ft.
Total	£2,120	£590
The more important items are:—		
Motor	300	60
Honeycombs (2)	75	35
Balance	350	250
Woodwork	1,000	80
Airscrew	35	50

We may now pass to the consideration of the methods which are used for supporting models in the channel.

Methods of Support

There is perhaps no more difficult part of an investigation into the wind forces acting on a model than that which is concerned with the increase of resistance due to the supports. The difficulty depends to a large extent on the kind of model which is under test. If the resistance of a sphere, or a square plate in normal presentation, was being investigated, it is unlikely that any appreciable error would be introduced by the assumption that the correction to be applied is given by a measurement of the resistance of the supports in the absence of the model. In the measurement of the resistance of a "streamline" body, however, an entirely different state of affairs exists. The resistance of an airship model 6 ft. long and 0.5 ft. in diameter is in some cases only about 1/100th of that of a square plate whose area is equal to that of the maximum cross-section of the airship model. Even though such a model is supported on a spindle about 0.3 in. in diameter, an error amounting in some cases to as much as 20 per cent of the model resistance would be introduced if this method of measuring spindle resistance were adopted. In the test of some models several alternative methods of test are available. Thus in experiments on aerofoils the method which is usually adopted is to mount the model with its span vertical, on a spindle screwed into its end.* An alternative method (which was adopted by Eiffel) is to support the model with its span horizontal on a spindle screwed into, for instance, its under surface, the spindle being constructed in such a manner that the angle of incidence of the aerofoil can be varied. In this case the support can be made of "fan" form, while in the former one it turns with the model, and is therefore circular. If a low-resistance aerofoil whose span is 18 in. and chord 3 in. is under test, the relative values of the spindle resistance in the two cases of span vertical and the span horizontal are about 60 per cent and 110 per cent of the minimum drag. These high values are caused by the length of spindle which must be exposed in order that the presence of the guard may not interfere with the flow round the model. It is therefore seen that the resistance of the spindle is nearly doubled when the span of the model is horizontal and though this is bad enough it does not constitute the most serious objection to the method. The method of evaluating the resistance of spindles have recently received a good deal of attention, and it has been shown that while, in the case of the spindle in the end of the model, the increase in resistance is not very different from that of the resistance of the actual spindle, there is much "interference" between the model and the spindle when the latter is attached to the under surface of the aerofoil.

It is therefore desirable, whenever possible, to test aerofoils with spindles in their ends; in cases (such as experiments on wing tips) where this cannot be done, great care must be taken in the determination of the resistance due to the support.

Stability

The question of stability of aircraft has been examined mathematically in considerable detail, the methods of developing the equations being laid down in Bryan's "Stability in Aviation." These methods have been developed by Bairstow, with the assistance of various members of the aeronautical

* Report Advisory Committee for Aeronautics, 1912-13, p. 77.

staff of the laboratory. In Report 77* the theories have been applied to the flight of an airplane, and were investigated for the case of an airship in 1916.

It is proposed to examine the methods which have been employed in measuring in the wind channel the various forces, moments, and damping co-efficients for models of actual machines. For the purpose of stability calculation the axes are supposed to be fixed in the machine, and the nomenclature which has been adopted at the laboratory is as follows:

Name of Axis	Symbol	Name of Force	Symbol	Name of Angle	Symbol	Name of Moment	Symbol
Longitudinal	X	Longitudinal	X	Roll	ζ	Rolling	L
Lateral	Y	Lateral	Y	Pitch	θ	Pitching	M
Normal	Z	Normal	Z	Yaw	ψ	Yawing	N

If the center of gravity is at *o*, the positive directions of the axes are as follows when the machine is in rectilinear flight in a horizontal plane: *ox* in the direction opposite to that of flight, *oy* to the left (*i.e.* to port), and *oz* vertically upwards. Forces are positive when acting along the positive directions of the axes, angles and moments are positive when turning occurs, or tends to occur, from *ox* to *oy*, *oy* to *oz*, or *oz* to *ox*. Angular velocities about the axes *ox*, *oy*, *oz* are represented by *p*, *q*, *r*, and linear velocities along them *x*, *y*, and *z*.

The rate of change of one quantity with regard to another of which it is a function is represented, in the usual manner, by writing the symbol for the latter as a suffix to that for the former. Thus the change of pitching moment due to pitching is represented on the system of axes chosen by Mq. The writer's experience has shown it to be desirable, if mistakes are to be avoided, that a system of axes, such as the one quoted, should be adopted for all wind channel work, and rigidly adhered to. The angle scale on the balance should be numbered in such a manner that rotation from X to Y increases the reading; the micrometer screw of the main moments apparatus should be graduated so that a moment which tends to turn the model from X to Y gives a reading greater than the zero. If the angle of pitch of a model is to be changed by rotation about a vertical axis, it should be mounted if possible with its under surface facing along the axis of Y. Forces, angles, and moments will now have their correct signs, except for normal force, for which the sign must be reversed. Care must be taken to correct the signs if the model is mounted in the reverse way, as is usually done in determining yawing moments on an unsymmetrical model.

Stability—We may now consider the determination of the quantities which must be known in order that the criteria of stability of a machine may be calculated. The first operation will be to mount the model in the channel in the usual way and determine the equilibrium forces on it. These results enable us to calculate (on the assumption that the wind forces vary as the square of the velocity) the resistance derivatives for variation of wind speed.

The derivatives for variations of velocity along the axes Y and Z are given by the curves of normal and lateral force for angles of pitch and yaw. If the angle base is degrees, the value of Zw/U or Yv/U is obtained by multiplying the slope of the curve near the origin of 57.3 to convert degrees to radians and dividing by the square of the wind speed.

It remains to measure the resistance coefficients due to oscillations through the equilibrium position, which have been called Rotary Derivatives.

The experimental determination of these quantities has already been described† in connection with tests on an airplane model, and though the apparatus has been modified, the same methods are in use at the present time.

Measurements were made by the method of observing oscillations, and only five of the more important derivatives were considered. These were:

The	Pitching	moment	due to	Pitching..... Mq
"	Rolling	"	"	Rolling..... Nr
"	Yawing	"	"	Yawing..... Lp
"	Rolling	"	"	Yawing..... Np
"	Yawing	"	"	Rolling..... Lp

The first three can be determined by observations of the damping of a natural oscillation, but the last two require that the model shall be oscillated about one axis while it is free to oscillate about another at right angles to it. The method was to set up an oscillation about the axis of yaw (or roll) and to adjust the period about the axis of roll (or yaw) till resonance was obtained. The motion about the first axis was then stopped and the decay of the motion about the second axis observed. The determination of these derivatives by forced oscillations was found, however, to be a matter of some difficulty, and the results can only be regarded as preliminary.

The remaining three derivatives—Lp, Mq, and Nr—were determined in the wind channel by observation of the damping of natural oscillations. The method for Mq and Nr was to mount the model on the balance in the same manner as for an experiment on the forces, the balance being free to rotate about a vertical axis. The motion was controlled by springs which maintained the oscillations for a period of from 20 to 40 sec. against the damping due to the wind forces and the friction of the apparatus. The damping of the oscillations was recorded photographically for several wind speeds. The reduction of the results consists in plotting the loge of the double amplitude on a "number of swings" base for each wind speed (including zero). These lines are approximately straight for the part of the curve over which the amplitude is reduced from its maximum value to half, and the logarithmic decrement is consequently determined from this slope. If the slope at zero wind velocity is subtracted from the slope at each of the other velocities and the result divided by the periodic time (T) at that wind speed, we get value of $\frac{h'}{2I}$ where h_1 is the damping due to the wind and I the moment of inertia. If each value is divided by the appropriate wind speed (U), we find that the damping to be nearly proportional to the speed. I can be calculated from the equation

$$T = \frac{2\pi}{\sqrt{\frac{k_1}{I} - \frac{h_o^2}{4I^2}}}$$

where T is the periodic time at zero wind velocity, k_1 the moment due to the apparatus, and h_o the damping due to friction. We can now obtain values of $\frac{h_1}{U}$, and if we neglect change of the coefficients with scale and speed we can calculate $\frac{BMq}{U}$ and $\frac{CNr}{U}$ by multiplying by the fourth power of the ratio of the dimensions of the actual airplane to those of the model, B and C being the moments of inertia in pitch and yaw respectively.

Scale and Speed Effect

In considering the application of model results there is one important correction which it is necessary to apply to the great majority of experiments in a wind channel; it is that for change of size and speed between the model and the actual machine. It has now been well established that for what may be called totally submerged bodies, such as aircraft or torpedoes, where the type of motion is determined by the viscosity of the fluid, we may write

$$F = \zeta v^2 l^2 f\left(\frac{vl}{V}\right)$$

where F is the resistance to forward motion, v the velocity, l a dimension of the body, and ζ and V the density and kinematic viscosity of the fluid. If the form of the function is unknown, we can only be sure that the motion in an experiment on a model will be similar to that on the actual machine if the value of $\left(\frac{vl}{V}\right)$ is the same in the two cases. This condition is usually unobtainable in wind channel tests, as both the size and the speed are much higher in practice; in the case of rigid airships the value of vl for the actual ship is some 200 times that in the model test. By carrying out tests in water v can be reduced to 1/14th that of air, but the experimental difficulties then become very great and in most cases outweigh the advantages of an increase in the value of $\left(\frac{vl}{V}\right)$. Experiments on full scale machines are admittedly extremely difficult, and it is only recently that they have been carried out on airplanes.

* Report Advisory Committee for Aeronautics, 1912-13, p. 135.

† Report Advisory Committee for Aero, 1912-13, p. 172.

It is hoped that in the near future resistance experiments on full-size airships will be made.

Experiments on models over the greatest possible range of speed appear, in many cases, to indicate that the power of the velocity which the resistance varies at is not very different from 2 at the highest value of $\left(\frac{vl}{V}\right)$ obtainable. If FaV^2, then $f\left(\frac{vl}{V}\right) = 1$, and we can calculate the forces on the actual machine directly from our model experiment.

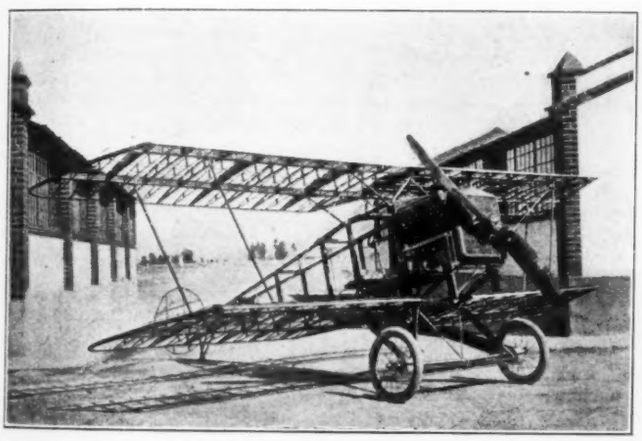
A very large amount of data has been obtained in testing the airplanes which are being constructed for our naval and military forces, and comparisons of the greatest value are now possible between the results on models and actual machines. The writer believes that the time is not far distant when the design of new machines will be essentially based on the results obtained in experiments on small-scale models in a wind channel.

It was the author's good fortune to be associated for some years with Mr. Leonard Bairstow, F.R.S., who was until recently the Senior Assistant in the Aeronautical Division of the National Physical Laboratory. The progress which has been made was due in a very large measure to his personal ability and to the sympathetic encouragement which led to such close co-operation between the members of the staff who worked under him.

The Mexican "Microplano" Scout

It is not generally known that during the last two years the Mexican government has made a considerable, and apparently quite successful, effort at building up a wholly national air service. This effort is mainly due to the untiring activity of Colonel Alberto Salinas, a nephew of President Carranza, who took his pilot license in 1912, at Mineola Aerodrome and has since been continuously identified with the development of Mexican aviation.

In November, 1915, an Aviation Department was created in the Mexican War Office, and a military aerodrome and flying school was established at Valbuena, near Mexico City, with Sr. Horacio Ruiz as chief pilot. For the tuition of the first pupils there was available a number of heterogeneous machines of American construction, such as Blériot and Morane type monoplanes, most of which had seen some service in the revolution.



THE "MICROPLANO" SCOUT, FITTED WITH A 150-HP. HISPANO-SUIZA ENGINE

SR. F. SANTARINI (IN THE MIDDLE), THE DIRECTOR OF THE MEXICAN AVIATION FACTORY

Eventually the need of a national source of supply became apparent and Colonel Salinas expanded the Valbuena aerodrome by the addition of a national aviation factory, the direction of which was entrusted to Sr. Francisco Santarini, an Italian engineer and aviator. The first product of the factory was the Anáhuac airscrew which was especially designed to fulfil the trying requirements of the Mexican climate, that is, rarefied air prevailing on the high plateaus, and terrific heat in summer time. In the latter respect the difficulties encountered by the American airplane squadron stationed in Texas, in 1916, were quite memorable, for the airscrews had to be kept during daytime in special humidors, lest they crack and the glue dissolve.

The next step was the construction of primary training airplanes. The greater part of these were tractor biplanes, although a small number of monoplanes, including a Morane parasol type, were also built, apparently for purposes of comparison. The engines used hailed from different makers, such as Gnôme, Anzani, Renault, Curtiss, etc., none of which exceeded 100 hp. A dozen or so aviators were trained on these machines and plans were then laid down for a further expansion of the aerial establishment.

Last year an engine department was added to the aviation factory, and there the first Mexican aero-engine, called the Aztatl, was produced. This engine is of the Anzani type, and is being manufactured in two models, one developing 70 hp. and the other 100 hp. Complete national source of supply having thus been provided for the training branch of the air service, plans were made for the fighting matériel.

Through an arrangement with the Hispano-Suiza Co. of Barcelona the rights of manufacture for their engines were acquired, and production of these high powered engines is soon to begin at Valbuena, if it has not already started. Machinery for this purpose appears to have been imported from Spain.

The latest product of the aviation factory is a one-seater scout, called "Microplano," which is described and illustrated herewith by courtesy of *Tohtli*, the Mexican aviation magazine.

Characteristics of the "Microplano" Scout

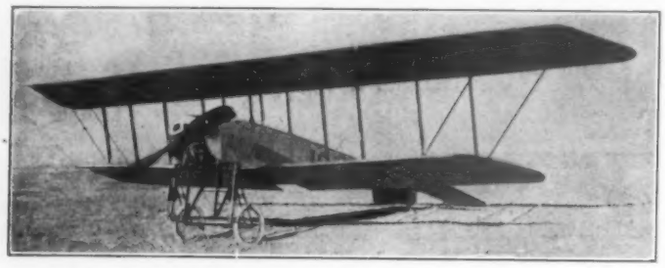
The "Microplano" was built to the designs of Sr. Francisco Santarini, chief of the aviation factory, and Captain Guillermo Villasana, chief of the Technical Section of the Aviation Department. Its characteristics are the following:

Overall span (top plane)	8.00 m.
Span of lower plane	6.80 m.
Surface area	18 sq. m.
Interplane gap	1.50 m.
Overall length	6.60 m.
Speed, horizontal	190-210 km.p.h.
Gross weight	650 kg.
Net weight	460 kg.
Useful load	190 kg.
Engine	Hispano-Suiza, 150 hp.
Airscrew	Anahuac, high power type

The Body.—The body is of rectangular cross-section, and is built up of wooden longerons and cross-pieces, suitably trussed with wire stays. At the rear the four longerons taper into a fine conical end, and are connected with one another by means

of a common fitting of steel sheeting which serves as a base for the elevator and rudder axles.

The Tail Planes.—The tail planes are entirely built of steel tubing, and are of the balanced type. The surface area of the



MEXICAN TRAINING BIPLANE, FITTED WITH A 100-HP. GNÔME ENGINE

elevators is 1.73 sq. m., that of the rudder, 0.76 sq. m. No fixed surfaces are carried abaft.

The Wings.—The wings are built up of two wooden spars and ribs of the same material, and have a general Morane aspect. The lower wings are fixed to the body by means of a universal joint, while the upper wings fit to a center panel which is carried by the body on two W-type struttings. The interplane connection on either side of the body consists of a pair of tubular steel struts which are slightly inclined to the outward, and of the usual lift and landing wires. Each wing structure weighs, uncovered, 10 kg., and is designed for a resistance of 140 kg. per sq. m.

The Power Plant.—The power plant consists of a water-cooled, 8-cylinder Hispano-Suiza engine, developing from 150 to 160 hp. at 1500 r.p.m., and a special Anáhuac airscrew.

The Undercarriage.—The undercarriage is of the V-type, with a divided axle sprung on rubber cord.

The Control.—The control is of the stick type, with a foot bar actuating the rudder.

Taken as a whole, the "Microplano" strikes one as a highly interesting machine, which distinct originality cannot be denied in spite of the fact that its general outlay is visibly inspired by the best French tendency in scout design. Considering that Mexican aviation, as a national industry, is only a little over two years old, one cannot withhold one's admiration at the sight of the astounding progress achieved by our Southern neighbors in so short a time.

The Artificial Seasoning of Wood*

By Professor Percy Groom, D.Sc., F.L.S.

The seasoning of timber is in essence a post-mortem process of drying conducted in such a manner as to permit of the wood being used as a structural material. It is necessary to emphasize the fact that the process is one conducted after the normal vital activity of the tree has been arrested, because it has been seriously but entirely erroneously urged in the courts of law that the term "mature" as applied to timber is a synonym of "seasoned."

In order to devise perfect methods and apparatus for artificially seasoning timber, it is necessary to understand the physical principles determining the drying of any material and the practical application of these to ensure equable distribution of heat and moisture among the drying objects. But it is also necessary to have full knowledge of the structure and properties of wood, as well as the effects induced in these properties owing to a change in the amount of water contained in the wood.

Construction of Wood

Wood is not a material; it is a structure, and varies in design and construction not only in the different kinds of timbers, but also in wood produced by one and the same species of tree. It is essentially composed of a material, allied to cellulose, that may be termed *wood-substance*, which is excavated into countless minute closed cavities of various shapes.

The structural constituents of wood thus are all hollow and shaped like narrow spindles, tubes, or bricks; their solid parts, composed of wood-substance, are termed "walls." Those constituents mainly dovetail with one another and their long axes are mostly parallel to the original long axis of the trunk or branch of the tree. But this main grain of the timber is crossed at right angles by bands of weak brick-shaped constituents; as these bands in the original trunk run transversely in a radial direction, they are termed "rays." Such rays are familiar as the cause of the silver grain of oak, beech, mahogany, and other woods.

These various structural constituents may contain in their cavities air, water, and substances dissolved in water, small quantities of various solids and occasionally resin, which is often contained in special local spaces created by the local separation of the structural constituents. The solid walls contain water and relatively small amounts of various complex organic substances.

From the present standpoint a piece of wood may be regarded as being composed solely of wood-substance, water, and air, for the other substances present represent only an insignificant fraction of the weight of the whole.

Water in the Green (Fresh) Wood

In the trunk of a sufficiently mature standing tree a considerable amount of water is contained in the outer wood (*sapwood*) and usually a smaller amount in the central wood (which, when differing in color from the outer wood, is termed *heartwood*). For instance, in the Scots pine (red deal) the sapwood is on the average about four times as moist as the heartwood. In other cases (*e.g.*, the oak) at times the sapwood and heartwood may contain almost equal amounts of water.

The Drying of Wood

The water present in the cavities (as opposed to the walls) can pass freely along the cavities and through the walls, so that when wood is dried this water readily evaporates, and a piece of wood containing more than 100 per cent (the percentage of water is best expressed as a percentage of the weight of the absolutely dry wood in which it was originally contained) of water is easily dried to a condition when the water is solely in the walls, and amounts to 25 to 30 per cent. Yet during the phase of drying, if the wood is being artificially seasoned at a high temperature, two opposite effects and defects may be induced so that ruptures arise in the wood. On the one hand, the rapid production of steam inside the closed hollow constituents creates pressures that suffice to burst the little chambers open and cause large splits in the timber. On the other hand, the drying timber may collapse along its grain; this collapse may be due to the evaporation of water from the hollow closed constituent being accompanied by little or no admission of air, until a thin film of moisture remains lining the wall; this film, by its contraction due to surface tension, exerts on the wall a pull that culminates in collapse.

After the evaporation of the water contained in the cavities, the remaining water is held with considerable force by the wood substance (walls), which therefore may be loosely described as being a hygroscopic material. Wood-substance, like a number of other organic materials (glue, gels, and so forth), shrinks when it loses water, and swells when it absorbs water. Thus, at least in very thin drying pieces, wood does not begin to shrink until it contains 25-30 per cent of water, and if it were possible to regulate the loss of water from a drying piece of timber so that evaporation was balanced by an equal flow of water from the interior, no shrinkage would take place until all the water in the cavities has been removed. Indeed, in the cases of many timbers no perceptible shrinkage takes place during the early phases of seasoning; when once the cavities have been depleted of water shrinkage begins, and is henceforth proportional to the amount of water lost.

Assuming that a piece of wood, not too thick, has reached this critical point and is exposed to the atmosphere at normal temperatures, it will continue to give off water vapor until the water in the wood-substance (at any rate, at the surface) is in equilibrium with the atmospheric moisture. This stage is reached, in our country, in the open air, but under cover when

* Paper read before the Institute of Automobile Engineers, London.

17-22 per cent of moisture is present. When brought into dryer outhouses, the wood becomes more fully seasoned and its humidity sinks to 13-17 per cent, while after being kept in rooms at least intermittently warmed, it attains a degree of dryness at which only 10-13 per cent of water is present. But in none of these cases is a final permanent degree of humidity attained; increase and decrease in the relative humidity of the atmosphere cause the wood respectively to absorb and emit water. It is partly to avoid such changes in the water-contents of wood, and the consequent changes of shape and size, that wooden articles are frequently coated with more or less impervious layers of varnish, paint, oil, paraffin wax, and so forth.

These various percentages of moisture, therefore, indicate the degrees of humidity to be aimed at in the artificial seasoning for articles that are to be used in the corresponding situations. Such is the usual *rationale* of the condition attained by naturally seasoned wood. There are, however, considerable qualifications to be added. On the other hand, it is known that in houses massive beams of oak, hundreds of years old, have been found to contain much moisture at the center; it is also known that articles of oak, however well seasoned, when their surfaces are replaned "move" and may crack at the surface. Those facts suggest that at least certain kinds of wood tend to acquire a relatively impervious surface, and that the inner wood in thick pieces of timber always contains a larger amount of water than corresponds to equilibrium with the local atmosphere.

Shrinkage and Warping of Wood

The shrinkage or swelling of wood-substance (walls of the constituents) occasions corresponding changes in dimensions of a piece of wood. These changes in dimensions are not equal in different directions, and therefore tend to be accompanied by changes of shape of the piece of wood. The cause of this lies in the het rogeneous structure of the latter. The elongation of the constituents along the grain causes a distinction between the transverse and longitudinal structure. The occurrence of the rays, and the concentric construction of the successive layers of wood, evoke differences in circumferential and radial structure. Shrinkage and swelling are unequal in all these cardinal directions; along the grain (longitudinally), and transversely in the radial and circumferential ("tangential") directions.

The fibers and other structural constituents of wood, like vegetable films in general, shrink and swell much less along their long axes than traversely. In drying from the green to the fully seasoned condition, wooden rods cut along the grain, transverse-radially, transverse-tangentially, usually show respectively the following shrinkages recorded in percentages of the original length, 0.1, 0.6, 0.6. The greatest cause of warping and splitting during drying is the disproportionately large circumferential (tangential) shrinkage when compared with radial shrinkage.

If we consider the seasoning of the trunk of a tree, it might appear impossible to secure this without the wood splitting, since the circumference tends to shrink twice as much for each end of length as does the resin. But wood is both extensible and plastic, so that a beam loaded at the center acquires a permanent set; hence it is possible to season wood without distortion or splitting, despite the tendency toward differential contraction.

If a piece of wood be dried too rapidly, so that the outer layers tend to shrink too quickly when compared with the inner wood, one of the following results ensues: either the piece warps or splits at the surface, or it undergoes a change known as case hardening, or there is a combination of these effects.

Case Hardening

Case hardening is almost universal in wood that has been seasoned too rapidly in a drying kiln. The name is appropriate, because where these defects exist the wood at and near the surface is different from that lying within, and, so to speak, forms around this a hard case. The wood is harder than if properly seasoned. It may or may not display superficial cracks or internal cavities that are pointed oval in a section across the grain of the wood. When such wood that has been fully dried throughout is planed along one face, it bends, becoming concave on the newly exposed surface, or if it be sawn through the middle, the two halves bend so that the fresh surfaces are concave. If, however, the hard case possesses well-developed cracks these curvatures do not take place. The *rationale* of these phenomena is as follows:

During rapid drying the superficial wood dries more rapidly than the water is supplied to it from within. It therefore tends to shrink, but its contraction is opposed by the internal wood, which has not lost sufficient moisture to cause it to shrink at the same pace (if at all). The inner wood, therefore, is in a condition of compression, while the outer wood is in tension. The latter being ductile resists rupture, but acquires a permanent set. The hard case of wood thus formed opposes the outward passage of water, so that the internal wood dries more slowly, and accordingly tends to shrink more.

Eventually a stage is reached when the inner wood has lost so much water that it tends to contract more than did the outer wood, so that the conditions of stress are now reversed, the outer wood being in compression and the inner in tension. As a consequence, at this phase internal splits may arise and widen out to form the oval "honeycomb" cavities already mentioned.

Wood completely dried continues to retain this peculiar stressed condition (excepting in so far as it is relieved by splits), and therefore bends *instantly* as it leaves the saw or planing instrument. Such bending differs from warping, which is caused by lack of uniformity in the distribution of moisture at the time of bending, and is the gradual result of differential tensions caused by subsequent drying.

A succession of the two kinds of bending takes place if a piece of wood in the first stage of case hardening be sawn through; for the newly exposed inner damp wood, liberated from its condition of compression, elongates, whereas the hard "case" remains constant in dimensions, with the consequence that the freshly exposed surface becomes convex. But as the wood dries the convexity changes to straightness, and finally to concavity as the damp wood dries. During the initial stages of case hardening, shallow cracks may arise in the outer hardening wood and partially relieve the tension. Such cracks may be subsequently closed in the second stage, when the hard case is in a condition of compression.

Warping and Splitting

The elementary facts in relation to the different amounts of shrinkage in the three cardinal directions fully explain such phenomena as the lack of warping in quartered or rift-sawn wood, the excessive warping or splitting of wood with curved grain (including burr wood), and partly justify the use of three-ply wood. Yet there remain many problems requiring solution as to the proneness of certain kind of timbers to warp or split, and to the causes determining whether a wood shall merely warp or merely spilt, or display both these defects.

Mention may now be made of a special additional case illustrating the effect of the mode of cutting timber in determining whether or not the latter will be successfully kiln-dried. In certain types of exotic timbers, the grain, in place of being straight, runs in successive layers alternately in right-handed and left-handed spirals, with the result that in a bastard-cut board the grain is not only oblique, but also appears to be interlocked. Such wood is truly cross-grained. A bastard-sawn board, when rapidly dried, is apt to twist, because longitudinal shrinkage on each face is least along the direction of the prevailing grain. When the effects on the two faces of the board agree in sense, a twisting couple is established. The prevention of this lies in cutting the trunk radially into boards —*i.e.*, producing solely quarter-sawn boards.

Amount of Shrinkage

Under like conditions the shrinkage (or swelling) of different kinds of timbers, of different samples of the same timber, or even of the various constituents of one piece of timber, is not the same. Taking the last case first, certain softwoods (coniferous timbers), when properly kiln-dried, or when installed in an incompletely seasoned condition as panels, become ribbed along the grain. The ridges and furrows correspond to alternating layers of light spring-wood and heavy summer-wood which have shrunk unequally.

It is often alleged that heavy woods shrink more than do light ones. This statement, though not devoid of some foundation, is often opposed to the truth. But to understand the matter fully it is necessary to consider the precise significance of the terms "heavy" and "light" as applied to woods.

Wood-substance composing the solid framework of all timbers is, within very small limits of variation, invariable in

specific gravity (1.56), being slightly more than half as heavy again as water. Hence, in comparing two pieces of wood of equal volumes and deprived of all water, the one is heavier than the other (almost) solely because it contains more wood-substance and less air. Consequently, when two pieces of wood of different (apparent) specific gravity, but containing the same percentage of water, are being seasoned, the amount of water lost during drying down to the same percentage of humidity is proportional to the apparent specific gravities of the two woods when absolutely dry. Thus for this reason alone a heavy wood seasons more slowly than a light wood under identical circumstances. Obviously, also, if a heavy wood and a light wood are first deprived of all the water in their cavities, subsequently the comparative amounts of shrinkage of the wood-substance of the two will be proportionate to their (dry) specific gravities, assuming that they ultimately contain the same percentage of water. This might cause us to anticipate that a heavy timber would shrink more than a light one.

Moreover, it has been found that specimens of wood rapidly dried in an oven at a high temperature shrink less than specimens of the same kind of wood that are dried more slowly. This fact (which as a generalization requires confirmation) might lead us to anticipate that the slowly drying heavy timber would shrink more than the more rapidly drying light one. But these anticipations leave out of count the fact that the minute architecture of different timbers varies widely. Thus the generalization in reference to the great shrinkage of heavier woods is not true. It is, however, the fact that the lighter softwoods season more rapidly and shrink less than the heavier hardwoods. Moreover, the shrinkage of different samples of the same kind of wood, and to some extent of different kinds of timber that are structurally very similar, is often proportional to the apparent specific gravity. The light-weighted wood of Weymouth pine (Canadian white or yellow pine) shrinks less than the heavier Scots or Baltic pine (red deal); in this case probably also because the former is richer in resin, which decreases shrinkage.

The preceding remarks at least partially explain why softwoods (coniferous timbers) are more easily and rapidly seasoned than are hardwoods, without inducing distortion and cracking, and why the seasoning can be conducted safely at higher temperatures in the case of the former timbers.

The structure of softwoods is relatively simple, for the timber is mainly composed of spindle-shaped fibers, which differ among themselves almost solely in that the spring-wood fibers have wider cavities and thinner walls than have those of the summer-wood. Moreover, the rays crossing these fibers at right angles are extremely thin, and consequently disturb the straight course of the fibers to a minimum extent.

Hardwoods, on the other hand, are complex in structure, and consist of various structural constituents that vary greatly in shape, width and thickness of wall. These include long thin-walled relatively wide tubes, varied fibers, and very short, often thin-walled, brick-shaped constituents. Crossing these are the rays, which may be so thick (*e.g.*, in oak) as to necessitate the curving of the grain round their flanks.

Objects and Effects of Seasoning

The objects and effects of seasoning wood are:

1 To decrease its weight.

2 To decrease its shrinkage, warping, and splitting when the wood is utilized for its final purpose.

3 To increase its strength (especially in compression), its limit and its co-efficient of elasticity, and its hardness (when measured by indentation).

4 To decrease its pliability and toughness both below and above the limit of elasticity.

5 To increase the power of resistance of the wood to decay.

A piece of timber by its loss of water during seasoning may lose more than 50 per cent of its original weight, and may gain 100 or even 200 per cent in strength. But when the seasoning process is carried far, however carefully this be done, wood tends towards brittleness. On the other hand, if one wishes to increase the pliability and plasticity of wood, one heats and moistens it, so that prolonged treatment with steam renders wood very pliable and plastic, and thus tends permanently to rob it of a portion of its elasticity. The significance of these facts will be evident when the different processes of artificial seasoning are considered.

Natural and Artificial Seasoning

In *natural seasoning*, the sun's rays constitute the source of heat, and natural atmospheric currents contribute to the drying process. In correspondence with the variation in climate and weather, the process is irregular and unregulated, sometimes being in abeyance and at some other times being too rapid. The timber is, consequently, liable to warp and split, to undergo decay, or to be attacked by boring insects. Yet natural seasoning, despite of its wastefulness and long duration, has one advantage: it yields wood mechanically superior to wood that is artificially seasoned by any but the best processes.

Artificial seasoning usually takes the form of *kiln-drying*, in which the source of heat is artificial, and drying may be aided by artificially induced currents of air of regulated humidity. When properly carried out it saves not only time but also material, and may yield wood perfectly suited for its ultimate purposes. In the past, however, artificial seasoning has been mainly applied to wood destined for use in furniture and other objects, in which standing qualities were the main feature aimed at, and in which mechanical defects, such as brittleness, were not of paramount importance. It may be stated now that, although artificial seasoning has been so successfully applied to certain kinds of timber that there is no evidence of any inferiority to naturally seasoned wood, much research and experiments will be required before we know how to accomplish this in the most safe and efficient manner in connection with other timbers.

Artificial Seasoning—Four means of regulating the evaporation of water from timber are available for use:

1 Supply of artificial heat.

2 Production of air currents.

3 Regulation of the humidity of the air.

4 Regulation of the pressure of the air (rarefaction).

Excesses in any of these is liable to cause the wood to be damaged or to delay the seasoning.

Early in the history of mankind the seasoning effect of *artificial heat* must have been discovered, for green sticks held in front of a fire become hard and strong, while various articles made in primitive fashion in the forest of freshly-felled beech are even in modern times hardened by holding them in the fumes rising from burning wood.

From such primitive beginnings there is but a slight step to the earliest types of *drying kilns*, in which the timber was contained in a room at one end of which was a furnace that was separated from the timber only by a screen; or the room possessed a perforated floor below which was a furnace burning sawdust, shavings and fragments of wood. Obviously in such cases, although ventilating chimneys were provided, uniform distribution of heat and uniform drying were impossible, and the wood near the source of heat dried too quickly and was largely spoilt.

Relatively ineffective was the mere placing of the heating arrangements outside the drying chamber, for again the timber packed towards the center dried more slowly than that outside.

Stewing or Prolonged Steaming of Wood

Before passing to the more modern types of seasoning kilns mention may be made of another process of dealing with green wood by means of heated water-vapor with no ventilation. The pieces of wood are piled directly on one another in a chamber that can be hermetically closed. After closing the chamber hot water-vapor, at a temperature above 30 deg. C., is admitted from numerous holes in a tube. This vapor penetrates the wood, condenses, and causes an outflow of colored sap, which sinks into the concave floor of the chamber. When the requisite pressure has been attained the steam pipes are closed for four or five hours. Thereafter the colored thick brown sap is evacuated through an outflow pipe. The process is repeated until the sap flowing out and condensing is colorless; this stage being reached in four to five days. The door and escape shaft are opened to admit a free current of air and to allow the wood to cool. Thereafter the wood is transferred to a drying kiln or allowed to dry for a longer time at normal temperatures.

The wood thus treated is seasoned in about four to five months instead of the two or three years that would be required for natural seasoning. Its properties are changed: sometimes its color is clearly modified, it is easier to work, warps less, and is said to possess increased powers of resisting, not only decay, but also attacks by insects. The treatment is akin to the prolonged steaming process by which beech wood is so changed that it loses its natural tendency to warp and split and acquires such redness of color as to facilitate its use as a substitute for mahogany.

Such processes of steaming are quite different from, and more prolonged than, those employed in rendering possible the permanent bending of beech and ash, or permanent compression of oak for railway keys.

The change in color that may take place in drastically steamed woods is thus accompanied by change in the properties of wood. These easily detected modifications are at least often paralleled by changes in the chemical composition of the steamed wood. Mere boiling water relatively soon breaks down wood-substance partially and causes the production of cellulose (cp. cotton wool), and hot steam occasions the same chemical degradation.

Thus, in considering the possible effect of steaming processes freely employed in certain drying kilns, it has to be remembered that steaming tends to soften wood, renders it temporarily pliable, and so robs it of its elasticity as to make it into a plastic material.

Mechanical Effects of Different Methods of Heating Timbers

Having considered the more obvious effects of the application of dry heat and of steam on wood, it is possible to view in greater detail some results obtained in experiments performed under the auspices of the Forestry Service of the United States on woods to which heat and moisture were applied in various ways. The accompanying table gives some of the results obtained:—

Nature of Treatment	White Ash						Loblolly Pine		
	Temperature, Fahr.	Duration of Treatment	Compression, Dry	Compression, Soaked	Bending, Dry	Bending, Soaked	Duration of Treatment	Compression, Dry	Bending, Dry
Dry air	145	25 days	(*c*)	(*c*)	(*c*)	(*a*) 5	26 days	(*c*)	(*b*) 2
Dry air	170	..	..	..	..	..	8 days*	..	(*b*) 6
Dry air	200	..	..	..	..	..	3 days*	(*c*)	(*b*) 5
Dry air	250	..	..	..	..	..	6 hours*	(*c*)	..
Saturated steam	212	1 hour	(*c*)	(*c*)	..	..	1 hour	(*c*)	..
Saturated steam	212	4 hours	(*c*)	(*c*)	(*c*)	(*b*) 2	4 hours	(*c*)	(*c*)
Saturated steam, 90 lb.	331	1 hour	(*b*) 27	(*c*)	..	..	15 min.	(*b*) 9	..
Saturated steam, 90 lb.	331	5 min.	(*b*) 4	(*c*)	(*b*) 3	(*c*)	4 hours	(*b*) 42	..
Saturated steam, 30 lb.	274	..	..	..	..	..	4 hours	(*b*) 11	(*b*) 10
Exhaust steam	145	19 days	(*c*)	(*c*)	(*c*)	(*c*)	22 days	(*c*)	(*c*)
Exhaust steam	145	..	..	..	..	..	22 days	(*b*) 2	..
Exhaust steam	170						2 days		
Superheated steam at atmospheric pressure	274	..	..	..	..	..	4 hours	(*c*)	(*c*)
Superheated steam at atmospheric pressure	331	6 hours	(*c*)	(*b*) 3	..	..	..	..	..
Superheated steam at 30 lb. pressure	298	..	..	..	..	..	4 hours	(*b*) 8	..

* Plus 26 days at 145° Fahr.

In the columns headed "Compression" and "Bending" are given the percentage changes in strength when compared with the wood naturally seasoned to the same degree of humidity: (*a*) denotes a gain in strength; (*b*) a loss; (*c*) no change. The columns headed "dry" refer to wood which was first naturally seasoned, then in this condition was subjected to the particular treatment indicated, and thereafter finally naturally seasoned for one year, and finally tested. The columns headed "Soaked" refer to wood which was naturally seasoned, then soaked with water, and in this wet condition was subjected to the treatment indicated, and subsequently tested after a year's natural seasoning.

The results of these tests may be summarized as follows:—

Exposure to a temperature of 145 deg. F., with dry air or exhaust steam, for nineteen to twenty-six days had little effect on the compressive or bending strength of the two timbers. An additional couple of days in exhaust steam or an additional eight days of dry heat at 170 deg. F. evoked signs of weakening.

Shorter exposures to saturated steam at 212 deg. F. (for up to four hours) or superheated steam at atmospheric pressure at temperatures 274 deg. F. and 331 deg. F. (for four and six hours respectively) caused no injurious effects.

But immediately that saturated or superheated steam at high temperatures, with the pressure at 30 lb. or more, is applied, weakening of the timbers quickly ensued. In saturated steam at 274 deg. F. at a pressure of 30 lb., pine was in four hours weakened about 10 per cent; at 331 deg. F. and 90 lb. pressure, ash was in five minutes weakened 4 per cent, and in one hour 27 per cent; while the pine was weakened 9 per cent in fifteen minutes and 42 per cent in four hours.

But when the ash was subjected in its soaked condition to saturated steam at 331 deg. F. with the pressure at 90 lb., no ill effects resulted; yet under the desiccating influence of superheated steam at the same temperature, but at atmospheric pressure, a weakening took place.

The significance of these results, particularly in relation to speeding up of artificial seasoning processes, is obvious, but is of limited scope, since these tests were merely static and gave no indication as to the shock-resisting powers of the treated woods. Tiemann, however, in giving an account of this research, states that the woods subjected to the high temperatures were more brittle than naturally seasoned.

Another effect of most of the treatments recorded in the table was that the woods treated subsequently showed reduced warping and shrinkage when compared with naturally seasoned wood. An abnormal darkening of the color of the wood was evident, especially when high temperatures were used.

Before passing away from the consideration of the effect of damp air upon wood, it may be mentioned that when the air is damp but merely warm, not only is the desiccating action low or non-existent, but the conditions favor the growth on the wood of molds and more virulent wood-destroying fungi. And there are on record cases in which seasoning timber or the woodwork of kilns have been damaged through this cause.

It is now obvious that each kind of timber must be treated in a special manner, and that the precise seasoning treatment of one and the same kind of timber will vary with the dimensions of the pieces to be seasoned and with the amount of water that they contain. Moreover, one piece of wood may consist partly of sapwood and partly of heartwood, and the latter will dry more slowly than the former. Moreover, no two planks from one tree contain the same percentage of water, and a single plank may show considerable inequalities of moisture along its length and always does show such inequalities at different distances from the surface.

Considerable amount of experiment and research will have to be undertaken before the practical solution of these difficulties is accomplished for various kinds of woods.

It is, however, evident that in a kiln it is necessary to ensure approximately equal heating of all the pieces of wood and equable removal of water from them. These aims are best accomplished by the supply of hot air that shall be freely supplied to all points of each piece of wood. Two methods widely differing in design are in use:—

1. In one the timber is ranged in layers tier upon tier, each being separated by a short distance from a corresponding layer of steam-heated pipes. Here the air is heated inside the kiln.

2. In other types hot air is admitted to the kiln from the floor or walls or from the end. Most of the modern kilns belong to this type and may be ranged into two sub-types:—

(*a*) The chamber or compartment type

(*b*) The progressive or tunnel type

The chamber type is illustrated by the Sturtevant kiln, which in its completest form has three main air-distributing ducts, supplying respectively warm dry, cold dry, and moist air. Branch ducts from each of these connect with each department or chamber, if there be more than one of these; the supply of air is regulated by dampers. The process of drying is as follows:—

1. Admission of moist cool air
2. Maintenance of humidity while the temperature is raised
3. Decrease in the relative humidity of the air and further rise of temperature.

Circulation of the air is secured by fans, one of which takes

fresh air, a part of which passes into the cold air ducts, and the rest passing through the heater and thence to the hot air duct. Another fan takes moist air from the chamber containing the wood and conveys any required amount of it to the moist air duct. Additional moisture may be liberated in the drying chamber by means of sprays.

Kilns of the compartment or chamber type are well fitted for simultaneously seasoning pieces of wood of various dimensions and even of different kinds. It is simple also to use in them autographic recorders of the temperature and humidity, so that model charts can be constructed to serve as guides for future operations. One other advantage is that the air currents are under control in all weathers and at all seasons.

In the tunnel type of kiln the timber is placed on trolleys and is moved forward along the tunnel day by day in the face of a current of air that meets it. This current of air is driest as it enters, and gains in moisture as it passes over the seasoning wood, and, therefore, moistened as it leaves the tunnel at the other end, where each batch of timber enters. In the modern Erith progressive dryer the air entering near the discharge end comes from below and descends at the end at which the timber is admitted, so that the circulation of air is rotary; a shaft permits the exit of excess of moist air. This system is especially valuable where large quantities of the same kind of timber of equal dimensions have to be seasoned.

The temperatures used vary from 70 deg. F. up to nearly 232 deg. F., according to different customs, and according to the purposes for which the wood is destined; the higher temperatures are especially used in seasoning softwoods (coniferous timbers).

It may be noted that experiments have been made on seasoning with rarefied air, but do not appear to have resulted in the evolution of any commercial kiln.

The account of seasoning of timber would be incomplete without mention of certain preparatory treatments sometimes adopted as a preliminary to either natural or artificial seasoning.

Timber is sometimes soaked or stored for a long time in water. This washes out some of the constituents, and therefore renders the timber less hygroscopic. It tends, therefore, to cause it to shrink slightly more, but swells slightly less than is normally the case.

Sometimes timber is soaked in salt water or treated with hygroscopic salts, such as commercial magnesium sulphate, or with a saccharine solution. Treatment with hygroscopic salts tends to reduce shrinkage but increase swelling.

In one process of soaking with saccharine solution, known as Powellizing, heat is the agent employed to induce penetration of the sugar.

In so-called "senilization" of wood solution of magnesium sulphate or other substances are caused to enter by continuous or alternating electric currents.

It is conceivable that the soaking with hydroscopic substances renders it possible to employ more rapid methods of drying without deleterious results; but this has not been demonstrated and therefore remains to be investigated.

The Fan Dynamometer

The brake horsepower of an engine is often measured by means of an absorption dynamometer. An absorption dynamometer may consist of a fan, mounted on the engine to be tested, the blades of which absorb a certain amount of power while being revolved in the air.

The brake horsepower may be computed as follows:

$$\text{B.hp.} = \frac{2\pi TN}{(12)33{,}000} = \frac{TN}{63{,}000}$$

Where N is the revolutions per minute of the engine tested and is easily measured; 33,000 is the equivalent of a horsepower in ft. lb. per min.; T is the torque or turning moment

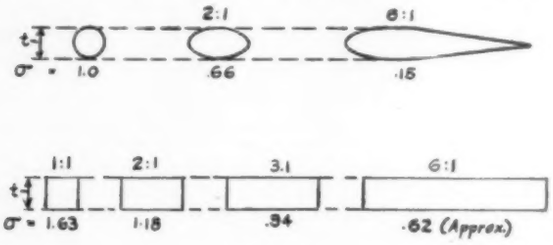


FIG. 1

in inch lbs., exerted by the engine shaft on the fan, and as the fan is rotating at a uniform angular velocity, is equal to the torque exerted by the air on the fan in resisting its rotary motion.

It is evident that the value of T depends on a number of quantities having to do with the angular velocity and the shape of the blades.

A fan dynamometer is simple in appearance, consisting of two paddle-shaped blades clamped at right angles to the engine shaft and separated from each other by 180 deg. The blades of course may be of any shape. Although square blades are usually used, round blades are to be preferred as they are much easier to make accurately and need no special care in alignment. The arms of the fan may be made of ash and the blades of birch ply-wood.

The torque can be divided up into two parts; that due to the arms alone and that due to the blades alone. Tests show that the torque due to the arms alone (Ta) may be given with sufficient accuracy by the formula:

$$Ta \text{ (inch lbs.)} = .35 \times 10^{-3}\, \sigma\, N^2\, (Ra)^4\, tW$$

Where σ is a coefficient depending on the section of the arms as given in Fig. 1; N is the r.p.m.; Ra is the radius shown in Fig. 2 (in inches); t is the thickness of the arms in inches and W is the density of the medium in which the fan rotates.

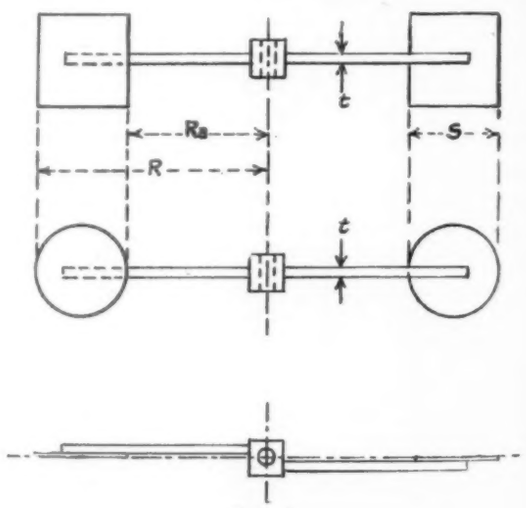


FIG. 2

$$W \text{ (for air)} = 2.7\frac{P}{T_{abs}}$$

Where P equals the absolute pressure of the atmosphere in lb. per sq. in. (barometer reading times .469) and T_{abs} is the absolute temperature in degrees Fahr. (459.5 plus thermometer reading).

Tb, the torque due to the blades alone, can be given by a similar expression:

$$Tb \text{ (inch lb.)} = KN^2 R^3 S^2 W$$

In this case R is the external radius of the fan in inches. S is length of one side of a square blade or the diameter of a round one, in inches. N and W have the same significance as in the equation for Ta. K is a coefficient depending on the value of $\frac{R}{S}$ and the shape of the blade.

$$\text{B.hp.} = \frac{(Ta + Tb)\, N}{63{,}000}$$

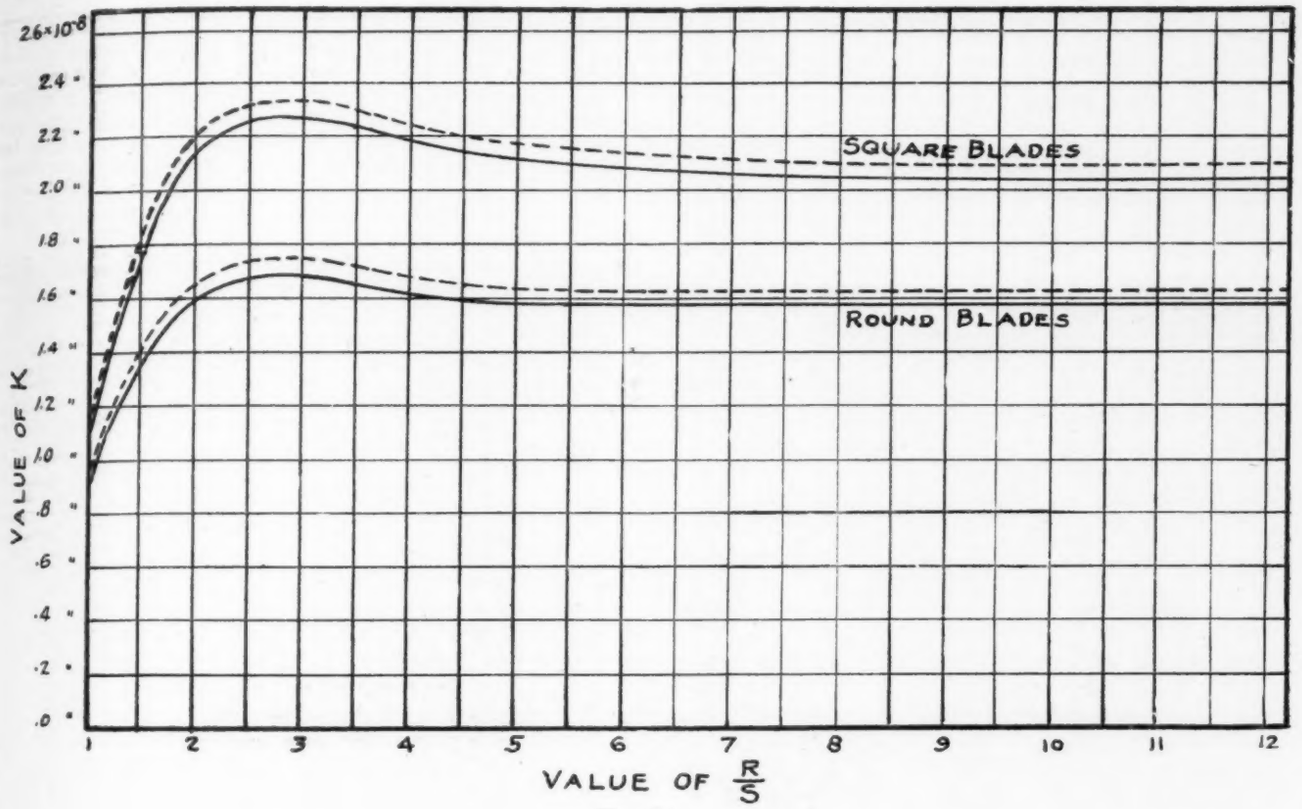


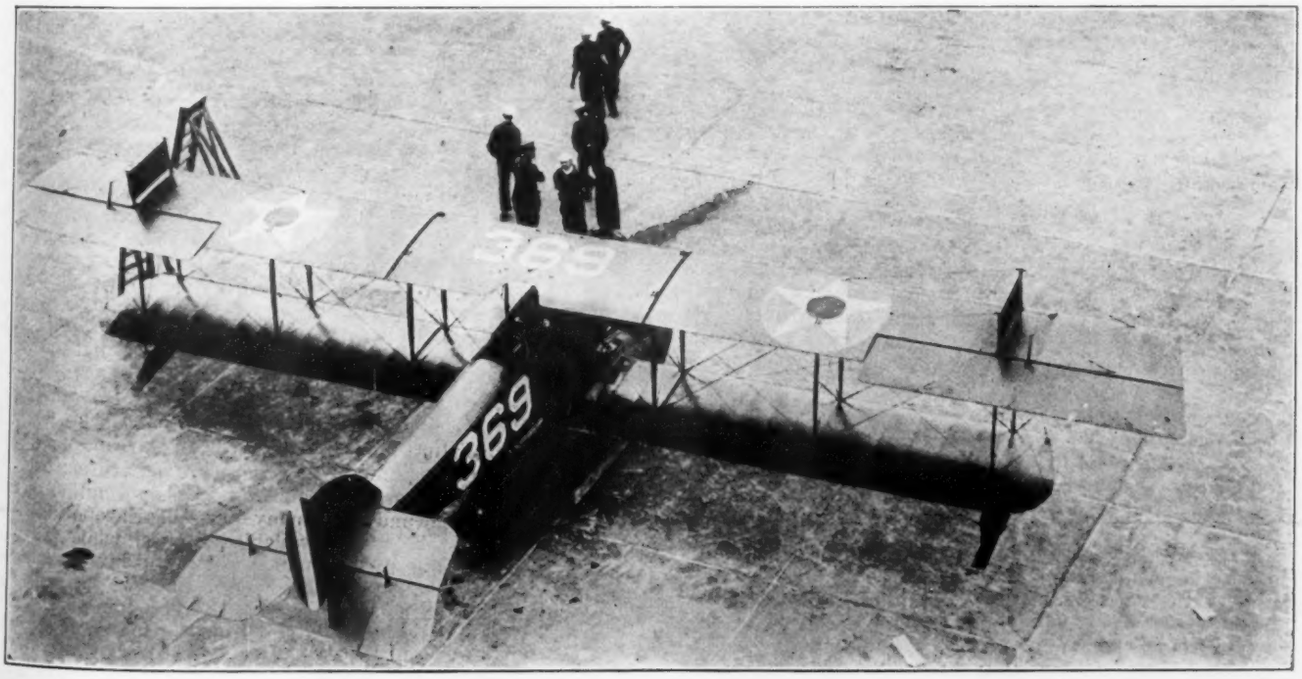
FIG. 3

A little thought will show why Ta and Tb vary according to the above expressions. The torque is proportional to the area. This brings t and Ra into the expression for Ta and S^2 into the expression for Tb. The pressure of the air on the fan would vary directly as the mass of air acted upon. This brings N, R and W into the equations. The pressure also depends on the change in velocity imparted to the air by the blades and as theoretically the air is turned through 90 deg., the pressure must vary as N and R again. The other R comes in because the torque depends upon the location of the air pressure with respect to the axis of rotation.

K is not as easily determined as the above quantities, but must be determined by experiment for different shaped blades and varying ratios of R to S.

The chart, Fig. 3, shows a reliable set of curves for square and round blades. As a point of interest it might be noted that the value of K for round blades approaches .7854 of the value for square blades, showing that K varies as the area for large values of R/S.

By means of the chart and the above equations, calculations for the proper size of fan may be made when the approximate engine speed and horsepower output are known.

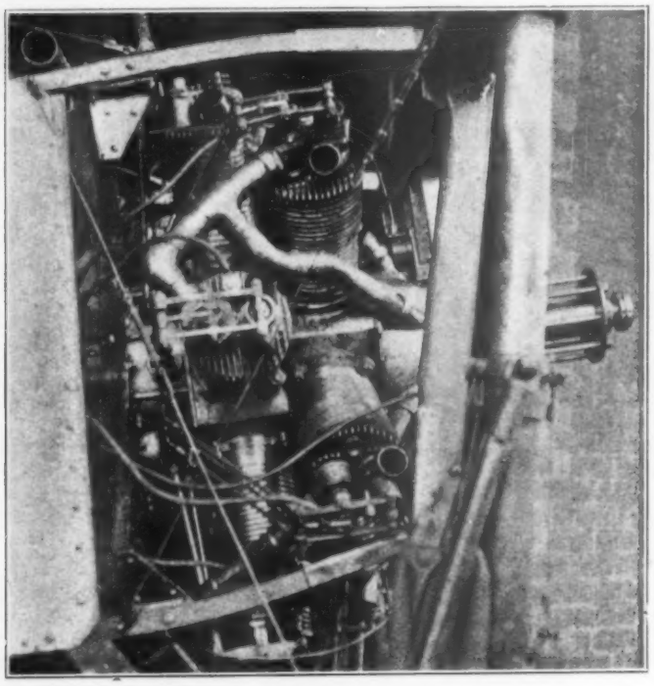


CURTISS TRAINING SEAPLANE OF THE U. S. NAVY
(C) Committee on Public Information

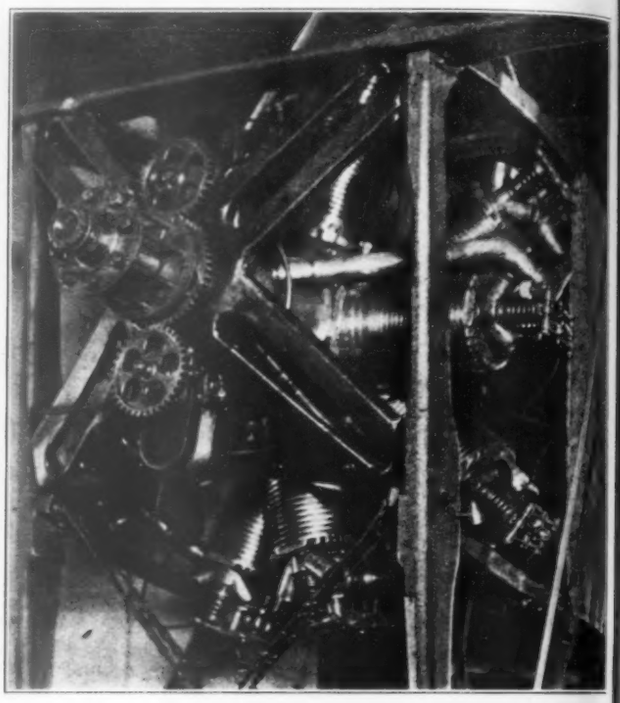
The Hudson Aero-Engine

The 10-cylinder, radial, air-cooled engine, illustrated herewith, has been developed on the Pacific Coast during the past seven years by the Western Aero Motor Co., to the designs of John W. Hudson.

The Hudson engine has ten air-cooled, steel cylinders of 4½ in. bore, arranged annularly in two sets of five, the cylinders of the second set being placed so that they come between, though back of, the cylinders of the first set, and hence receive in flight the full blast of air.



SIDE VIEW OF THE HUDSON ENGINE MOUNTED ON A MONOPLANE



FRONT VIEW OF THE HUDSON ENGINE WITH ITS ENGINE PLATE

The cylinders have the usual steel flanges cut upon them and are provided with cast iron liners in which the pistons, also of cast iron, fit with a liberal clearance. The liners provide a better wearing surface of the same kind of metal as the pistons and there is not the liability of pistons seizing that there is when steel cylinders alone are used.

The five connecting rods of each set of cylinders are pivoted to a master ball-bearing on the crankpin, and ball-bearings are also used at each end of the crankshaft. The engine is lubricated by a force-feed oiling system, oil being pumped through the hollow crankshaft by means of a gear pump. All the wrist pins and cylinders receive oil through the hollow connecting rods.

The use of ball-bearings in aeronautical engines is becoming more general. The bearings in this particular engine are said to have run 200 hr. without showing sign of wear.

Generous-sized intake and exhaust valves are located in the cylinder heads, all the valves being operated from two large cam rings on the crankshaft. Special twin pusher rods and rocker-arms operate the exhaust valves, while a single rocker and push rod between them operate the intake valve. There are five intake pipes. The gas passes from a special carbureter through the hollow crankshaft into the crankcase, whence it goes through the five intake pipes to the cylinders.

The cooling effect of the evaporating gasoline is very marked and has much to do with the proper cooling of the engine. The carbureter is of the floatless type. It has a positive needle valve that feeds the fuel as required. Both a throttle and auxiliary air valve are connected to this needle valve. The whole device is positive.

The Hudson engine develops 100 hp. at 1200 r.p.m. and 120 hp. at 1500 r.p.m. Its weight complete is 300 lb. or three pounds per horsepower.

The fuel and oil consumption is claimed to be but six and one gallons an hour, respectively.

The Flying Boats of the R. N. A. S.

When the Admiralty representative in the House of Commons was challenged to mention the name of anyone in the Royal Naval Air Service who had ever produced an airplane which had been of use in war, the only name he could give was that of Comdr. John Porte, R. N. If the challenge had been to mention anyone whose design might have been of use, says *The Aeroplane*, he could have mentioned Flight-Commander Dyott, whose twin-engined biplane flew well, and anticipated both the Handley-Page and the Gotha. Or if questioned as to future possibilities he might have mentioned the designer of a miniature machine produced by the Royal Naval Air Service experimental station, though probably he would not have done so. However, as things were, Commander Porte's was the only name available.

Everyone interested in sea-flying, friends, enemies and neutrals alike, knows of the existence of the Porte flying boat, though one hopes that the enemy does not know all the details thereof. It must suffice, therefore, to say that what the Handley-Page, the Riesenflugzeug and the Caproni are to land-going airplanes, the Porte boat is to the seaplane.

From a discouraging American experiment it has become a great British—or rather Irish—success: for Commander Porte is as Irish as if his name had been O'Sullivan, and he comes from the same county. What the Porte boat has done against submarines and airships, with equal facility, may not be told till after the war, but one may safely say that it has more than made good; it has proved itself one of the most valuable British weapons. As an airplane it is of exceptional capacity, and as a boat it assures the safety of its crew when a seaplane of the ordinary type would guarantee for them a liquid end.

The Porte boat is one of the few aerial vehicles which is certain of a future immediately after the war, and no matter how the war may end, for as a means of navigation over the waterways of unorganized countries, such as South America, Africa and Asia, and even many parts of Europe and Australasia, it can be made available at once, while the local people are making up their minds whether to lay out labor on aerodromes for land-machines or not. Pending the arrival of the absolutely reliable aero-engine, the big flying-boat is the solution of the trans-oceanic and trans-marine problem, especially if combined with the "super-marine" wing-slipping arrangement.

International Aircraft Standards

4P3—Specifications for Plain and Ball Head Bolts for Aircraft

GENERAL.—1. The general specifications, 1G1, shall form, according to their applicability, a part of these specifications.

USE.—2. These bolts are to be used in plane construction.

MATERIAL.—3. These bolts shall be made of alloy steel conforming to I. A. S. B. specification 383. The bolts shall be machined preferably from heat-treated, cold-drawn bars. They shall first be copper-plated in a cyanide bath and then nickel-plated; the coating shall not exceed 0.001 in. (0.0254 mm.) in thickness.

HEAT TREATMENT.—4. Unless made from heat-treated, cold-drawn bars, the bolts shall be heat treated after machining to give the required physical properties.

PHYSICAL PROPERTIES AND TESTS.—5. The bolts must have the following physical properties:

Tensile Test.—(*a*) The breaking load of the bolts tested in tension between the head and nut shall not be less than the area of the root of the thread multiplied by 100,000. The minimum breaking loads calculated in this manner are given in the tables below.

Bend Test.—(*b*) The bolts shall withstand being bent cold through 180 degrees around a pin of thickness equal to the diameter of the bolt. If the bolt is not long enough to be subjected to this test, the threaded portion must withstand being bent cold through 35 degrees.

TABLE 1.—DIMENSIONS AND TOLERANCES FOR PLAIN HEXAGON HEAD BOLTS

Diameter.	Threads per inch.	A. Maximum.	A. Minimum.	Pitch diameter. Maximum.	Pitch diameter. Minimum.	B.	M.	Minimum breaking load.
Inch.		*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Pounds.*
0.164	32	0.164	0.160	0.1460	0.1440	0.312	0.125	1,170
0.190	32	0.190	0.186	0.1680	0.1660	0.375	0.125	1,630
0.216	32	0.216	0.212	0.1930	0.1910	0.375	0.125	2,240
0.250	28	0.250	0.246	0.2268	0.2248	0.437	0.156	3,130
0.312	24	0.312	0.308	0.2854	0.2833	0.500	0.188	5,070
0.375	24	0.375	0.371	0.3479	0.3457	0.562	0.219	7,860
0.437	20	0.437	0.433	0.4050	0.4027	0.687	0.250	10,610
0.500	20	0.500	0.496	0.4675	0.4651	0.750	0.281	14,510
Mm.		*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Kilogms.*
4.17	32	4.17	4.07	3.708	3.658	7.93	3.17	530
4.83	32	4.83	4.73	4.267	4.216	9.52	3.17	740
5.49	32	5.49	5.39	4.902	4.851	9.52	3.17	1,020
6.35	28	6.35	6.25	5.760	5.710	11.11	3.97	1,420
7.93	24	7.93	7.83	7.249	7.196	12.70	4.76	2,300
9.52	24	9.52	9.42	8.837	8.781	14.29	5.56	3,570
11.11	20	11.11	11.01	10.287	10.229	17.46	6.35	4,830
12.70	20	12.70	12.60	11.870	11.810	19.05	7.14	6,600

TABLE 2.—DIMENSIONS AND TOLERANCES FOR BALL HEXAGON HEAD BOLTS

Diameter.	Threads per inch.	A. Maximum.	A. Minimum.	Pitch diameter. Maximum.	Pitch diameter. Minimum.	B.	M.	Minimum breaking load.
Inch.		*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Pounds.*
0.164	32	0.164	0.160	0.1460	0.1440	0.312	0.172	1,170
0.190	32	0.190	0.186	0.1680	0.1660	0.375	0.172	1,630
0.216	32	0.216	0.212	0.1930	0.1910	0.375	0.172	2,240
0.250	28	0.250	0.246	0.2268	0.2248	0.437	0.203	3,130
0.312	24	0.312	0.308	0.2854	0.2833	0.500	0.250	5,070
0.375	24	0.375	0.371	0.3479	0.3457	0.562	0.313	7,860
0.437	20	0.437	0.433	0.4050	0.4027	0.685	0.359	10,610
0.500	20	0.500	0.496	0.4675	0.4651	0.750	0.375	14,510
Mm.		*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Kilogms.*
4.17	32	4.17	4.07	3.708	3.658	7.93	4.37	530
4.83	32	4.83	4.73	4.267	4.216	9.52	4.37	740
5.49	32	5.49	5.39	4.902	4.851	9.52	4.37	1,020
6.35	28	6.35	6.25	5.760	5.710	11.11	5.16	1,420
7.93	24	7.93	7.83	7.249	7.196	12.70	6.35	2,300
9.52	24	9.52	9.42	8.837	8.781	14.29	7.94	3,570
11.11	20	11.11	11.01	10.287	10.229	17.46	9.13	4,830
12.70	20	12.70	12.60	11.870	11.810	19.05	9.53	6,600

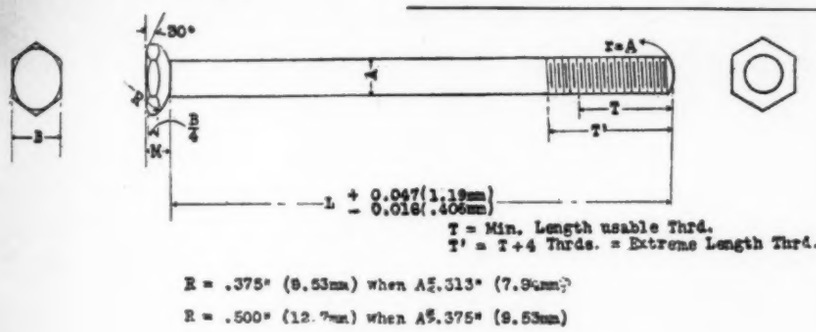


FIG. 1

One per cent of each size of bolt shall be subjected to both the tensile and the bend test.

DIMENSIONS AND TOLERANCES.—6. The bolts shall be of the form shown in figures 1 and 2 and shall conform to the dimensions within the tolerances given in Tables 1 and 2. The values given represent the finished dimensions after copper and nickel plating.

DELIVERY, PACKING, AND SHIPPING.—7. The bolts shall be delivered in boxes of gross weight not exceeding 50 lb. (22.7 kg.); the lots of individual sizes shall be packed in strong manila envelopes or cartons.

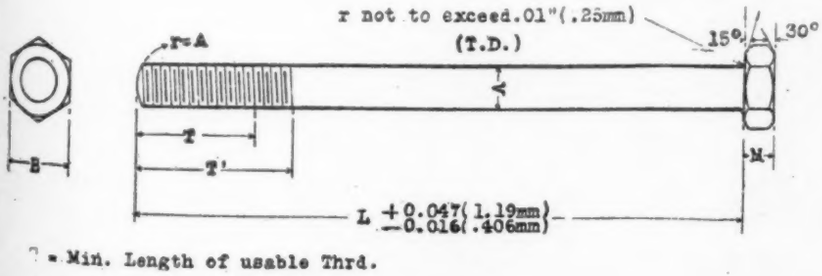


FIG. 2

3S19—Specifications for Galvanized Steel Service or Locking Wire

GENERAL.—1. The general specifications, 1G1, shall form, according to their applicability, a part of these specifications.

USE.—2. This wire shall be used for locking nuts and turnbuckles.

MATERIAL.—3. The wire shall be manufactured of either I. A. S. B. standard steel No. 1015 or No. 1020.

MANUFACTURE.—4. The wire shall be furnished in the soft-annealed condition, and shall be evenly and smoothly galvanized.

WORKMANSHIP AND FINISH.—5. The wire shall be cylindrical and smooth and must show no evidence of scrapes, splits, cold shuts, rough, or other defects.

PHYSICAL PROPERTIES AND TESTS.—6. The tensile strength must not exceed 75,000 pounds per square inch (52.7 kg./sq. mm.).

SELECTION OF TEST SPECIMENS.—7. When the wire is being unreeled to form small coils for shipment, specimens may be taken from the first, last, and any intermediate coil in the presence of an inspector who shall seal the small coils. Otherwise specimens shall be taken from 10 per cent of the coils for each size.

DIMENSIONS AND TOLERANCES.—8. (*a*) All wire for this purpose shall be furnished in decimal sizes corresponding to the American Wire Gage (Brown & Sharpe gage).

(*b*) A permissible variation of 0.002 inch (0.051 mm.) above gage on all sizes will be accepted, but no wire will be accepted having a variation of more than 0.0005 inch (0.013 mm.) below gage.

DELIVERY, PACKING, AND SHIPPING.—9. (*a*) Wire covered by this specification shall be shipped in coils or bundles wrapped closely with a layer of plain strong paper in strips no less than 3 inches (76.2 mm.) wide and then covered with another wrapping of waterproof paper of an approved quality.

(*b*) The size and weight of packages or coils shall conform to the following unless otherwise specified on orders: 0.072 inch (1.828 mm.) and larger, mean diameter of coils 22 inches (559 mm.), minimum weight of coil 25 pounds (11.34 kg.);

0.064 inch (1.628 mm.) and smaller, mean diameter of coils 8 inches (305 mm.), minimum weight of coil 10 pounds (4.54 kg.).

INSPECTION AND REJECTION.—10. A tag supplied by the manufacturer and filled in by the Government inspector with ink, showing the number of the test as per his official list of tests, the diameter of the wire, and the breaking strength, shall be attached to each coil or piece of wire accepted by him or by the salvage board. Such tag shall be sealed on the bundle with a steel wire of approved design and a lead seal bearing the private mark of the inspector doing the work.

CHEMICAL COMPOSITION OF STANDARD CARBON STEELS

Number.	Carbon.	Manganese.	Phos., maximum.	Sulph., maximum.
1015....	0.10-0.20	0.30-0.60	0.045	0.050
1020....	0.15-0.25	0.30-0.60	0.045	0.050

3N13—Specifications for Soft Solder

GENERAL.—1. The general specifications, 1G1, shall form, according to their applicability, a part of these specifications.

MATERIAL.—2. Solder shall be made from new tin and commercially pure new lead. Its composition shall be as follows:

	Per cent
Lead and tin, minimum	99.8
Tin	49 to 51
Antimony, maximum	10
Zinc	None.

DELIVERY, SHIPPING AND PACKING.—3. Solder shall be delivered in 1-lb. bars. The mark "Half and half" shall be cast on each bar. The bars shall be packed in boxes, the gross weight of which shall not exceed 220 lb. (100 kg.).

REFERENCES.—4. United States Navy Department Specification No. 4787.

4P4—Specifications for Plain, Ball, and Castle Hexagon Nuts for Aircraft

GENERAL.—1. The general specifications, 1G1, shall form, according to their applicability, a part of these specifications.

USE.—2. These nuts are to be used on bolts (I. A. S. B. specification 4P3.)

MATERIAL.—3. The nuts shall be machined from cold-rolled or drawn steel, I. A. S. B. specification 3S20.

MANUFACTURE.—4. The nuts shall be

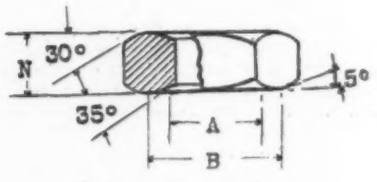


FIG. 1.—PLAIN NUT

NOTE.—Thread chamfer to be omitted on sizes smaller than 0.250-in. diameter

cyanide hardened. The nuts shall be copper-plated in a cyanide bath and then nickel-plated; the coating shall not exceed 0.001 in. (0.0254 mm.).

WORKMANSHIP AND FINISH.—5. The inside face shall be flat and free from burrs.

PHYSICAL PROPERTIES AND TESTS.—6. Nuts shall withstand having the inside diameter increased 25 per cent by drifting without cracking. One per cent of each size of all nuts shall be subjected to the drift test.

DIMENSIONS AND TOLERANCES.—7. The nuts shall be of the form shown in figures 1, 2, and 3, and shall conform to the dimensions within the tolerances given in Tables 1, 2, and 3. The values represent the finished dimensions after copper and nickel plating.

TABLE 1.—DIMENSIONS AND TOLERANCES FOR PLAIN NUTS

A, Bolt size. *Inches.*	B, Width across flats. *Inches.*	N, Thickness. *Inch.*	A, Bolt size. *Millimeters.*	B, Width across flats. *Millimeters.*	N, Thickness. *Millimeters.*
0.112	0.250	0.094	2.85	6.35	2.39
0.138	0.313	0.109	3.51	7.94	2.79
0.164	0.375	0.125	4.17	9.53	3.18
0.190	0.375	0.141	4.83	9.53	3.57
0.216	0.438	0.156	5.49	11.11	3.97
0.250	0.438	0.188	6.35	11.11	4.76
0.313	0.500	0.234	7.94	12.70	5.95
0.375	0.563	0.281	9.53	14.29	7.14
0.438	0.688	0.328	11.11	17.46	8.33
0.500	0.750	0.375	12.70	19.05	9.52
0.563	0.875	0.422	14.29	22.23	10.72
0.625	0.938	0.469	15.88	23.81	11.91
0.688	1.000	0.516	17.46	25.40	13.10
0.750	1.063	0.563	19.05	26.99	14.29
0.875	1.250	0.656	22.23	31.75	16.67
1.000	1.438	0.750	25.40	36.51	19.05

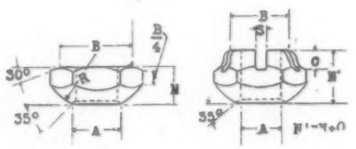


FIG. 2. BALL NUT

NOTE.—Chamfer to be omitted on sizes smaller than 0.250-in. diameter

TABLE 2.—DIMENSIONS AND TOLERANCES FOR BALL NUTS

	Ball hexagon.				Ball castle			
A, Bolt size.	B, Width across flats.	N.	R.	B.	N'.	S.	O.
Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
0.164-32	0.375	0.172	0.375	0.375	0.250	0.078	0.078
0.190-32	0.375	0.172	0.375	0.375	0.250	0.078	0.078
0.216-32	0.438	0.172	0.375	0.438	0.266	0.078	0.094
0.250-28	0.438	0.203	0.375	0.438	0.297	0.078	0.094
0.313-24	0.500	0.250	0.375	0.500	0.344	0.078	0.094
0.375-24	0.563	0.313	0.500	0.563	0.438	0.125	0.125
0.438-20	0.688	0.359	0.500	0.688	0.484	0.125	0.125
0.500-20	0.750	0.375	0.500	0.750	0.563	0.125	0.188
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
4.17-32	9.53	4.37	9.53	9.53	6.35	1.98	1.98
4.83-32	9.53	4.37	9.53	9.53	6.35	1.98	1.98
5.49-32	11.11	4.37	9.53	11.11	6.75	1.98	2.38
6.35-28	11.11	5.16	9.53	11.11	7.54	1.98	2.38
7.94-24	12.70	6.35	9.53	12.70	8.73	1.98	2.38
9.53-24	14.29	7.94	12.70	14.29	11.11	3.18	3.18
11.11-20	17.46	9.13	12.70	17.46	12.30	3.18	3.18
12.70-20	19.05	9.53	12.70	19.05	14.29	3.18	4.76

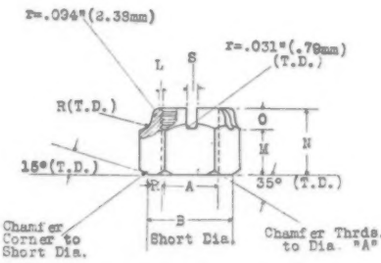


FIG. 3.—CASTLE HEXAGON NUT

NOTE.—Thread chamfer to be omitted on sizes smaller than 0.250-in. diameter

TABLE 3.—DIMENSIONS AND TOLERANCES FOR CASTLE HEXAGON NUTS

A, Bolt size.	B, Width across flats.	N.	S.	O.	M.	L.	R.
Inch.	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*	*Inch.*
0.164-32	0.375	0.234	0.078	0.078	0.156	0.016	0.094
0.190-32	0.375	0.250	0.078	0.078	0.172	0.016	0.094
0.216-32	0.438	0.266	0.078	0.094	0.172	0.031	0.094
0.250-28	0.438	0.281	0.078	0.094	0.188	0.031	0.094
0.313-24	0.500	0.328	0.078	0.094	0.234	0.031	0.094
0.375-24	0.563	0.406	0.125	0.125	0.281	0.031	0.125
0.438-20	0.688	0.453	0.125	0.125	0.328	0.047	0.125
0.500-20	0.750	0.563	0.125	0.188	0.375	0.047	0.125
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
4.17-32	9.53	5.95	1.98	1.98	3.97	0.40	2.38
4.83-32	9.53	6.35	1.98	1.98	4.37	0.40	2.38
5.87-32	11.11	6.75	1.98	2.38	4.37	0.80	2.38
6.35-28	11.11	7.14	1.98	2.38	4.76	0.80	2.38
7.94-24	12.70	8.33	1.98	2.38	5.95	0.80	2.38
9.53-24	14.29	10.32	3.18	3.18	7.14	0.80	3.18
11.11-20	17.46	11.50	3.18	3.18	8.33	1.19	3.18
12.70-20	19.05	14.29	3.18	4.76	9.53	1.19	3.18

DELIVERY, PACKING, AND SHIPPING.—8. The nuts shall be delivered in boxes of gross weight not exceeding 50 lb. (22.7 kg.). The lots of individual sizes shall be packed in strong manila envelopes or cartons.

3N15—Specifications for Brass Wire for Brazing

GENERAL.—1. The general specifications, 1G1, shall form, according to their applicability, a part of these specifications.

MATERIAL.—2 (*a*) The composition of the material shall be as follows:

	Per cent.
Copper	78-82
Zinc	Remainder
Total impurities, not greater than	1.2
Lead, maximum	0.1
Iron, maximum	0.1

Analysis.—(*b*) An analysis shall be made of samples taken from 1 bar of each lot of 25.

MANUFACTURE.—3. (*a*) The bars shall be made from lake or electrolytic copper, conforming to the I. A. S. B. specification 2N2, and from virgin spelter conforming to the I. A. S. B. specification 2N3.

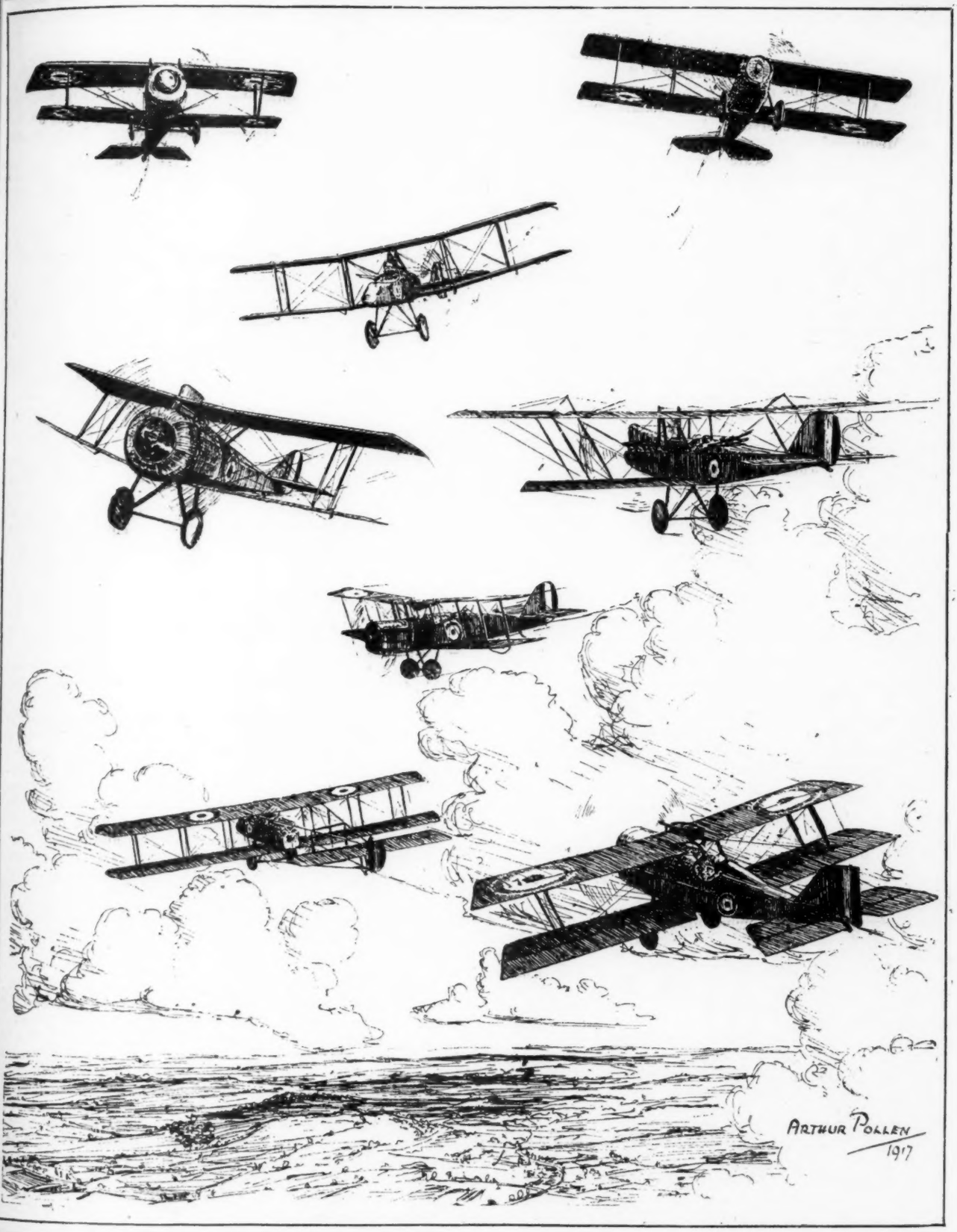
(*b*) No scrap shall be used in the manufacture of these bars other than that produced in the manufacturer's own plants and which is of the same composition as the material specified.

DELIVERY, SHIPPING, AND PACKING.—4. The wire shall be from 0.187 to 0.25 inch (4.76 to 6.35 mm.) in diameter and shall be furnished in bundles or coils of net weight not exceeding 220 pounds (100 kg.).

Fly to Camp Meade

Two British aviators, Lieut.-Col. Charles F. Lee and Capt. B. T. Marston, of the Royal Flying Corps, braved a gale recently in order to fly from Washington to Camp Meade, Md.

TYPES OF BRITISH AIRCRAFT



The above plate by A. J. L. Pollen, reproduced by courtesy of *Flying* (London), gives a striking comparative view of modern British military airplanes.

Digest of the Foreign Aeronautical Press

Flying (London), January 16, 1918

Captain Ball's Successors.—Captain Ball has many successors in the R.F.C. who carry on his tradition. Captain McCudden and Captain Fullard have suddenly blossomed into fame, and the newspapers have been full of their exploits. Captain McCudden, M.C., has brought down thirty-seven enemy machines, and his squadron has ninety-nine aircraft to its credit. At Mons he was an Air-Mechanic, and in the retreat he became an Observer. As a N.C.O. he won the Military Medal and the Croix de Guerre. Since he became a Flying Officer in a single-seater scout he has been in over a hundred fights, including three combats with Immelmann. His father was a warrant officer in the Royal Engineers, and was born at Carlow. His mother is Scottish. He will be twenty-three in March. He was born in barracks at Chatham. His career proves that the R.F.C. is recruited from the ranks as well as from the public schools.

Captain Fullard, M.C., D.S.O., has brought down forty-two enemy machines and three balloons. In one day he brought down four German airplanes. Before breakfast one morning he and a brother officer brought down seven machines, of which he was responsible for three. His squadron up till October had brought down 200 machines, and their "bag" is now about 250. For three months he worked with a flight of six pilots without a single casualty, and during that period they brought down more machines than any other flight in France. His goggles were shot away in a fight with a two-seater, and he brought his burning machine back safely. He is the son of the late Mr. T. F. Fullard, of Hatfield. He was educated at Norwich Grammar School. He went to the front in April, 1917.

The Aeroplane (London), February 6, 1918

The German Air Raids on Great Britain in 1917.—The following list gives detailed survey of the German air raids on Great Britain during 1917.

March 1.—One German airplane raided Broadstairs at 9.50 a. m. One woman killed.

March 16.—One German airplane raided Westgate-on-Sea at 5.30 a. m.

March 17.—German airships raided the South Eastern Counties of England. Bombs dropped in Kent.

April 5.—German airplanes raided Kentish coastal towns at 10.45 p. m. Eight bombs were dropped.

May 7.—One German airplane raided North-East London at 12.40 a. m. Four bombs were dropped. One man killed, and one man and woman injured.

May 24.—Four or five German airships raided East Anglia. One man killed.

May 25.—Sixteen German airplanes raided South East England (German Communiqué says Folkestone) between 5.15 and 6.30 p. m. Killed, seventy-six; injured, 174. Admiralty claim three brought down.

June 5.—Sixteen German airplanes raided Thames Estuary and adjoining districts of Essex and Kent and establishments in the Medway (German Communiqué says Sheerness) at 6.30 p. m. Killed, twelve; injured, thirty-six. Two machines brought down.

June 13.—Fifteen German airplanes raided East End of London, North Foreland, and the banks of the Thames at 11 a. m. Killed, ninety-seven; injured, 439. Germans claim one British machine brought down. The raid was of 15 minutes duration.

June 17.—Two German airships raided East Anglia and Kent. One Zeppelin brought down. Six bombs in Kent. Two killed, sixteen injured.

July 7.—About twenty German airplanes raided London, Isle of Thanet and East Coast of Essex (German Communiqué says Margate) at 9.30 a. m. One machine brought down by R.F.C. Fifty-nine killed, 193 injured.

July 14.—Twelve or fourteen German airplanes raided Harwich at 7 a. m. British claim two machines brought down on return journey off Belgian coast. Eight killed, twenty-two injured.

July 22.—Fifteen to twenty-one German airplanes raided Felixstowe and Harwich at 8 a. m. One machine brought down by R.F.C. off Belgian coast. Germans claim all airplanes returned. Thirteen killed, twenty-six injured.

August 12.—Twenty German airplanes raided Margate and Southend. At 5.15 they appeared off Felixstowe going South. Forty bombs dropped at Southend. Twenty-three killed, fifty injured. One machine brought down.

August 22.—One or two German airships raided Mouth of the Humber at 11.15 a. m. Twelve explosive and thirteen incendiary bombs dropped. One man injured. Ten German airplanes raided Ramsgate, Margate, and Dover at 1.10 p. m. Eleven killed, thirteen injured. Two machines brought down.

Sept. 2.—One German airplane raided Dover. Seven bombs dropped. One killed, six injured.

Sept. 3.—Six German airplanes raided Chatham, Isle of Thanet, Sheerness (German Communiqué says Ramsgate) between 10.40 and 11.30 p. m. One killed, six injured.

Sept. 5.—Twenty German airplanes raided London at 10.30 p. m. (German Communiqué says Margate and Southend as well.) Nine killed, forty-nine injured. One machine brought down off Sheerness.

Sept. 24.—German airships raided coast of Yorkshire and Lincolnshire between midnight and 3 a. m. Three injured.

Sept. 25.—German airplanes raided London and South East England at 7.45 p. m. Seven killed, twenty-five injured.

Sept. 27.—About twenty German airplanes raided London, Suffolk, Essex and Kent. No casualties. Two machines brought down.

Sept. 29.—German airplanes raided London, Kent, and Essex between 8 and 9 p. m. Eleven killed, eighty-two injured.

Sept. 30.—German airplanes raided London, Kent, and Essex at 6.40 and 8 p. m. Nine killed and forty-two injured. One machine brought down.

Oct. 1.—German airplanes raided London, Essex, and Kent between 7 and 10 p. m. Ten killed, thirty-eight injured.

Oct. 19.—German airships (six or seven) raided London and East and North Eastern Counties. Thirty-four killed, fifty-six injured.

Oct. 29.—German airplanes attempted to raid the South Eastern Counties. No casualties.

Oct. 31.—One airplane raided Kentish coast at 4.30 a. m. No casualties.

Nov. 31.—German airplanes raided London, Kentish and South East coasts at 10.45 and 11.50 p. m. Eight killed, twenty-one injured.

Dec. 6.—About twenty-five German airplanes raided London, Kent, and Essex at 1.30, 4.00, 4.30 and 5 a. m. Seven killed, eleven injured. Two machines were brought down.

Dec. 18.—Sixteen to twenty German airplanes raided London, Kent, and Essex between 6.15 and 9 p. m. Ten killed, seventy-five injured. Two machines were brought down.

Dec. 22.—German airplanes raided the Kentish coast at 6 p. m., when one machine was brought down, and at 9.30 p. m., when bombs were dropped in the Isle of Thanet. No casualties.

The Aeroplane (London), January 30, 1918

Veneered Spars and Struts.—It is a well-known fact that the present methods of applying silver spruce to aircraft construction are very wasteful, for nearly 50 per cent of the wood has to be cut to get the requisite degree of lightness for struts and spars. England is now suffering from a famine of woods suitable for aircraft, but particularly of silver spruce, and this famine is due as much to transport troubles as to the wastage inherent to aircraft manufacture. The rapid depreciation of service airplanes further contributes to render this problem a serious one.

To overcome these difficulties, which might eventually hamper aircraft supply, a British lumber concern has recently placed on the market hollow spars which are built up of thin veneers glued together to any desired section, strength, shape and length. No matter what the length of the desired spar may be, no scarfing or other joint is required, and uniform strength is given the spars over the entire length.

The same method is adopted for building up engine bearers and streamlined struts for interplane connection and undercarriages. These struts and spars are all reinforced in their interior construction in such way as to give the greatest resistance to all stresses and strains without adding to the weight of the pieces.

News of the Fortnight

American Built "Battle Planes" on Way to Front

The following statement is authorized by the Secretary of War in order to give as complete a picture as is permissible under military requirements of the problems and the progress in equipping the air service with fighting planes.

The first American-built battle planes are en route to the front in France. This first shipment, though in itself not large, marks the final overcoming of many difficulties met in building up this new and intricate industry.

Equipped with Liberty Motor

These planes are equipped with the first Liberty motor from machine production. One of them in a recent test surpassed all records for speed and climbing for planes of that type. Engine production, which began a month ago, is now on a quantity basis and the peak of production will be reached in a few weeks. Only the 12-cylinder type is being made, as developments abroad have made it wise to concentrate on the high-powered engine instead of the eight-cylinder.

These statements should not be exaggerated but should be considered in the light of the following facts: After three years of warfare the total number of planes able to take the air at any one time on either side of the western front has not been over 2500. This, combined with the fact that 46 men are required on the ground for every plane in the air, gives a truer perspective of the European aviation situation than commonly possessed.

Replacement Planes

For every plane in the air there must be two replacement planes on the ground, and one training plane for every pilot who eventually reaches the front, with a spare engine for each plane. Moreover, while the American program has been delayed by difficulties which were impossible to foresee when the tentative program was adopted in all our lack of knowledge last spring, it may be said that American planes are not due in France under the original schedule until July.

At the outbreak of war, the first step, both in sequence and importance, was to build up an industry to rush out the training planes needed for the prospective aviators who were immediately on hand. This fresh and most promising personnel afforded indeed America's largest immediate source of aid to her associate nations in the war, which, while well able to turn out the latest type of airplanes, were seriously drained of men capable of manning them. The ultimate goal, however, was the construction of a large fleet of battle planes.

Two serious problems, interwoven and reacting, were immediately met, the almost total lack of airplane industry and of airplane engineering knowledge. The industry was rudimentary, with only one company on an appreciable production basis and another dozen small experimental companies. The metal work was mostly done by hand, each machine built as a separate unit and little attempt made to manufacture from dies, jigs, or gages. The estimates of the total value of the industry vary from $2,000,000 to $10,000,000 and of employes from 5000 to 10,000. The government was practically the only purchaser, having ordered 366 planes the year before the war, of which only 66 were actually delivered.

Difficulties in Europe

The engineering problems were even more complex. Europe, at war, with the best engineers of each country pitted against each other in a struggle which knew no close, had worked out the most ingenious developments in the light of actual fighting experience. Information reaching here was generally fragmentary and always late. As a result, when war came, the United States had practically no airplane engineering staff and no modern fighting planes.

Construction of planes presented a much more complex problem than that of engines, which had been developed and produced here for other purposes on a colossal scale. The extreme refinement of their manufacture, requiring 23,000 screws in a single fighter, or 700 pieces of wood in a single wing, necessitated the most expert workmanship and balance to secure the essential combination of lightness with strength, and seemed to militate against quantity production.

Securing Information

The first step was to secure information from Europe. A commission was early sent across and rushed back the last-minute details, upon the strength of which a large number of fighting planes of a certain type were ordered. The raw materials were very largely in hand and the drawings within several days of completion when another cable said that this type had been superseded and should not be built. Nearly a month was thus lost.

Drawings then came for another type. They had just been redrawn for American manufacture and the die makers put to work when a second and different set arrived. The work done had to be cast aside and the process begun over again. Just as it was nearing completion still a third set of drawings arrived, and a third start was necessary. The unavoidable loss of time was preferred to turning out a design known at the outset to be out of date.

The effect of separation from the battlefields by 3000 miles is further shown in that anywhere from 17 days to 11 weeks have been required to secure various important samples from abroad. Another three weeks of day and night work is necessary to reduce these samples to drawings for American manufacture. It is significant of the rapid development of the art of aviation that not a single type of the original schedule has survived into the present program.

During the past month, however, a responsive channel of communication with the Allies has been opened, the latest types adapted to American manufacture, the industry increased at least twentyfold, the training-plane problem solved, and the production of battle planes begun. It is still very necessary, however, to view America's effort in aviation against the true perspective, both in this country and in Europe.

Need for Skilled Men

The great problem now remaining is to secure the thousands of skilled mechanics, enginemen, motor repair men, wood and metal workers, etc., needed to keep the planes always in perfect condition. This great engineering and mechanical force at the airdromes, the flying fields, and the repair depots, both here and behind the lines in France, is a vital industrial link in the chain to air supremacy. Without them the planes turned out would soon be useless and the flyers helpless.

At best the life of a plane is but two months, and the engine must be overhauled after 75 hours, while a pilot on a plane allowed to leave the hangars in imperfect condition is as helpless as a bird with a broken wing. Now that American battle planes are going overseas, a great increase in the volunteering of skilled mechanics is both essential and expected.

Aeronautical Work of the Bureau of Standards

The war work of the Bureau of Standards, including aeronautic tests and developments on the Liberty engine and airplane materials, was championed recently by Representative Towner in a speech backing the item of $250,000 for the Bureau of Standards, in the $1,000,000,000 Urgent Deficiency Bill which was passed by the House of Representatives on Feb. 18. Mr. Towner said, in part:

"I think there is no other bureau of the Government that is now rendering any more valuable service to the Government in the war preparations than is the Bureau of Standards.

"As an illustration, let me call attention to what they have been doing in aid of aero construction, the determination of standards and types, and the general work of preparing our air service. Their assistance has been exceedingly valuable in almost every stage of the work.

"In the developments and modifications that have been made of the Liberty engine, and especially in the development of the materials that are to be used in the manufacture of aircraft, the Bureau of Standards has rendered invaluable service. It was supposed that mahogany was the only wood which could be used for the construction of propeller blades. By the work of the Bureau of Standards the fact has been developed that a good many of our native woods may be used, upon proper tests, so that we shall have no difficulty in finding within the confines of our own country all the necessary materials for that purpose. It was supposed that nothing except linen could be used for the covering of the wings. It has been determined by experiments made by the Bureau of Standards that cotton may be made almost, if not entirely, equal to linen for this purpose if properly prepared."

Postal Airplane Bids Are Opened

Three bids for building five airplanes which will be used on the first route of the Aerial Mail Service were received by the Post Office Department on Feb. 21. Those bidding were the United Eastern Airplane Company, $59,000, delivery in 80 days; the Standard Aero Corporation, $68,000, delivery in 63 days; the West Virginia Aircraft Company, $72,500, delivery in 90 days. The bids were opened in the office of James Edgerton, purchasing agent of the Department, but no awards have yet been made.

All the bidders called for more time than was specified in the requests of the Department, which called for delivery by April 25.

Second Assistant Postmaster-General Otto Praeger and an Army officer recently went to Philadelphia to select landing sites for the airplane mail service which the Post Office Department will put into operation some time in April.

After examining a number of sites in Philadelphia they left for New York, where they will make another inspection. It is understood that the Polo Grounds, Governors Island and a part of Central Park are being considered as possible landing sites.

National Advisory Committee for Aeronautics Meets

The National Advisory Committee for Aeronautics met in the committee rooms on Feb. 23, where discussions on many phases of the work were held. The subjects under discussion were, however, refused to the press.

Among those members who attended the meeting were Dr. Charles D. Walcott, Dr. W. S. Stratton, Maj.-Gen. George O. Squier, Chief Signal Officer; Prof. J. F. Hayford, Lieut.-Comdr. Towers and Mr. J. F. Victory, Assistant Secretary. Major Tulasne and Captain de Berroeta, members of the French mission, also attended the session.

Dr. W. F. Durand, chairman of the National Advisory Committee for Aeronautics, is now in Europe, where, it is stated, he will establish a foreign bureau for the committee. His office will probably be located in Paris, where information relative to the latest development in aeronautics, especially as concerns the war, may be gathered and forwarded immediately to headquarters in Washington. It is understood that this system will probably do away with the present delay in the receipt of this necessary information in Washington.

Camera Repair School

An aviation photographic repair school where several hundred Army photographers, camera mechanics and repair men are to be taught the use of aerial cameras and kodaks, including their repair and upkeep, is to be established at Syracuse, N. Y., it is reported.

Men are to be sent there from camps and aviation fields for training and new recruits are to be mobilized there shortly.

This school is to be under the Signal Corps of the United States Army, and will probably be the only one of the kind completely given over to this work in the country. It is reported that the school will be laid out at once and training begun as soon as the men can be mobilized.

Navy Wants Homer Pigeons

The Aviation Section of the Naval Flying Corps is anxious to secure a large number of carrier pigeons for use in transmitting messages from seaplanes. When a seaplane is not in the air the radio apparatus cannot be used since it swings below the machine, and for this reason carrier pigeons are desired in order that naval aviators may send messages back to the base if the machine is wrecked or forced to descend or for other reasons.

Breeders of carrier pigeons or private individuals having any birds which they are willing to dispose of, should communicate with Ensign A. J. Ditman, Bureau of Ordnance, Navy Department, Washington, D. C.

National Hardwood Lumber Association Service Bureau

The National Hardwood Lumber Association, composed of all the largest hardwood lumber manufacturers and dealers in the United Statets, has established a war service bureau with offices in the Munsey Building at Washington, D. C. It is the object of this bureau to keep track of all the hardwood lumber on hand in this country and act as a clearing house in this connection. Services are also to be rendered to the Government and the Allies in an advisory capacity without charge.

The headquarters of this body is located in the McCormick Building, Chicago.

Americans at Inter-Allied Standards Meeting

On Feb. 25 the Aircraft Board issued the following statement:

The arrival in England is announced of delegates from all the Allied countries for conference on International Standards, at which a standardization of manufacturing materials as related to the production of machinery, engines, aircraft, etc., will be considered.

The American delegation, headed by F. G. Diffin for the Aircraft Board, includes members from all the prominent engineering societies of the country: The Society of Automotive Engineers, the American Society of Mechanical Engineers, the American Society for Testing Materials, etc. There are also members from the Aircraft Board, the National Advisory Committee for Aeronautics, the Signal Corps, the Navy and the original International Aircraft Standards Board, from which this conference is an outgrowth.

The purpose of this inter-Allied meeting, which is the result of the efforts of Mr. Diffin, is to enable better industrial service to be given with less man-hour effort, through relieving plants from carrying in stock non-standard materials for which there is small call, and concentrating on materials of known performance for the same work.

No attempt will be made by the conference to standardize airplane constructions, but rather only those materials and units which are at present causing confusion in purchase and delivery and for which suitable standards can be established.

The following is the list of the American members: F. G. Diffin, chairman; Dr. W. F. Durand, Lieut. Comdr. Benjamin Briscoe, Lieut. W. F. Prentice, Coker F. Clarkson, E. H. Ehrman, Charles M. Manley, James Hartness, Albert L. Colby, Friethiof G. Ericson, Capt. A. B. Tilt and F. R. Baxter.

New Naval Air Stations Recommended

In a preliminary report by the Commission on Navy Yards and Naval Bases, just made, the following recommendation is submitted:

"From a study of strategical requirements the Commission is led to believe that the first line of special defense for the Gulf of Mexico should be in the Florida straits and the Yucatan channel. An operating base will be necessary for submarines, destroyers and auxiliary vessels assigned to these localities. Key West seems to be better located strategically for this purpose than any other site available."

It is also recommended that a coastal air station, be established at Brunswick, Ga., and Tampa, on St. Andrew's Bar, Fla., and Mobile, Ala., also was cited as a good location for aircraft stations. If necessary, the report states a station might be established at Sabine Pass, Tex., though it is not a very good site for the purpose.

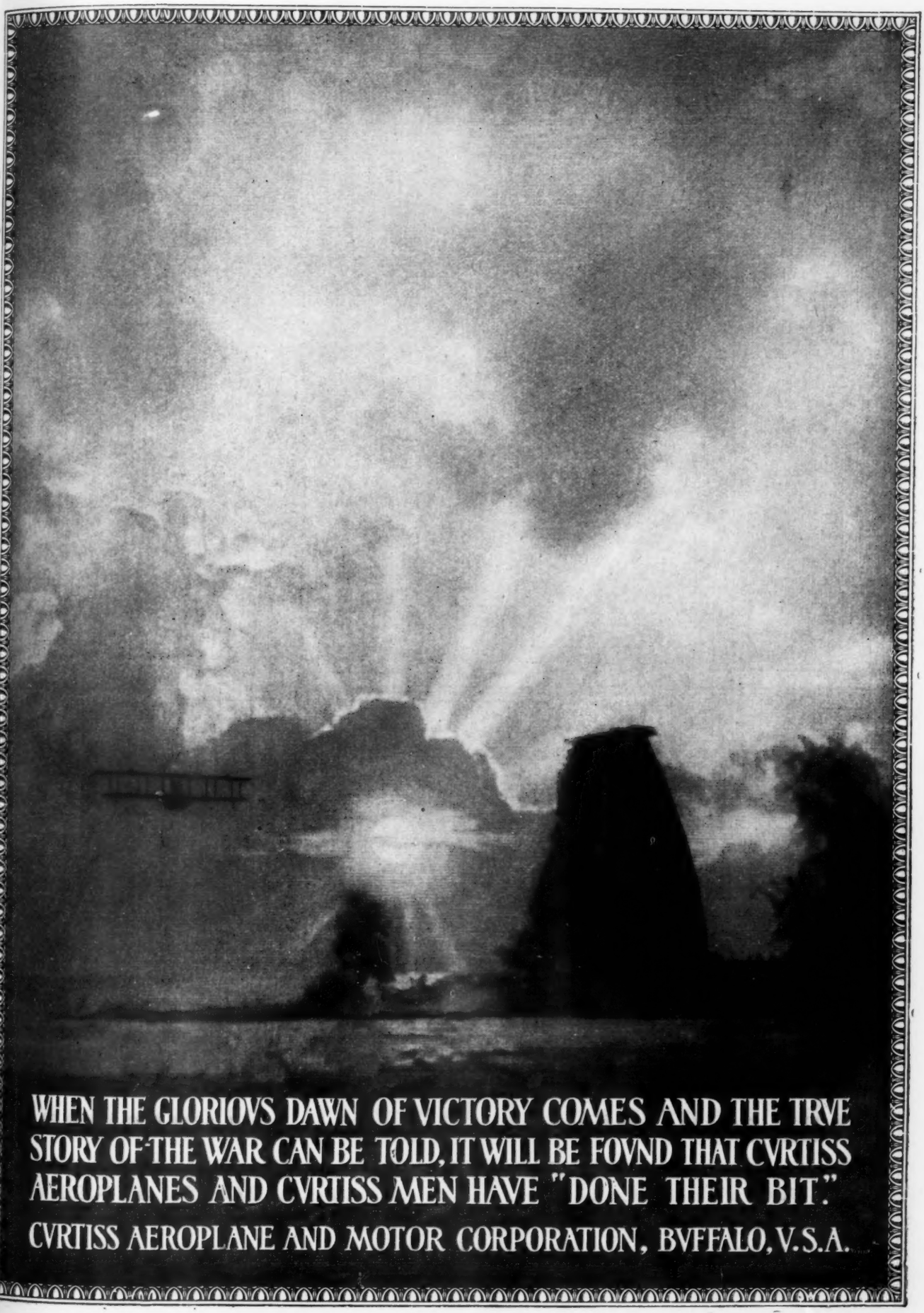
On the Pacific coast a main aviation station at San Diego, Cal., a base aviation station at Puget Sound and Mare Island Navy Yards and an operating aviation station at Port Angeles, Wash., are also recommended.

Deficiency appropriations for the Army and Navy, including large sums for aviation purposes, were reported by the sub-committee to the House Committee on Appropriations last week.

Training Aviators in Trap-Shooting

Trap-shooting as a method for training aviators at ground schools in the principles of hitting moving objects in the air has proved to be of the utmost value. The instructors claim that a few trials at the traps soon show whether a man will ever be able to wing an enemy airplane or not.

The idea of the practice is not to train the men in the use of handling the guns, for only shotguns are used, but to develop quickness of the eye and judgment of the speed and direction of moving objects. The problem of winging a hostile plane with a machine gun is not widely different from that of smashing a four-inch clay disc with a shotgun and the experience the men get in learning how far to lead the target, how much time to allow for speed of the shot and fall of the target will prove invaluable in the real work. While practice counts a great deal in this game, a man must have a certain knack in handling a gun if he is ever to make a success of it. The shooters stand sixteen yards behind the trap, which makes the actual range of shooting between forty and sixty yards.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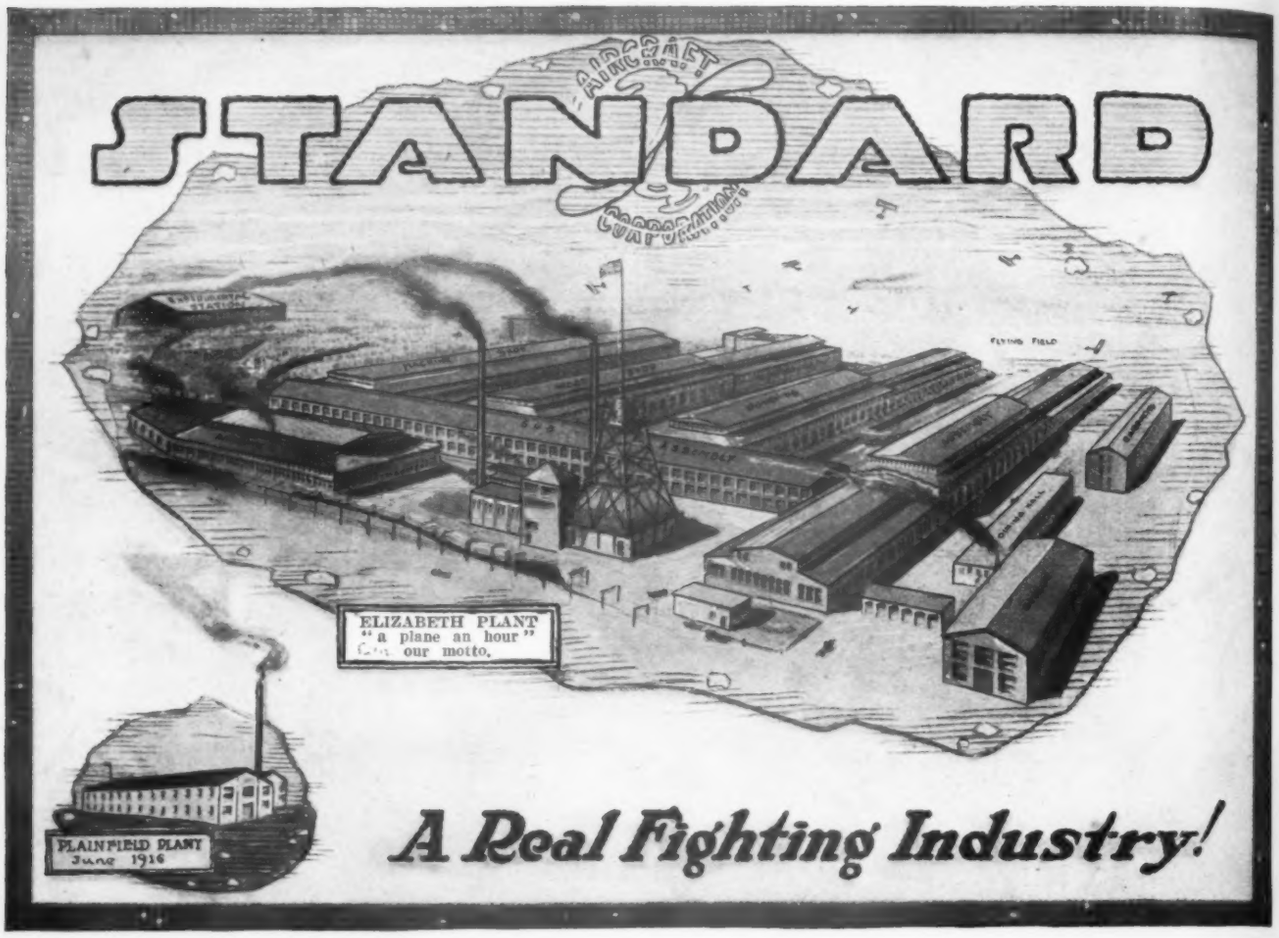

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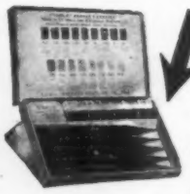

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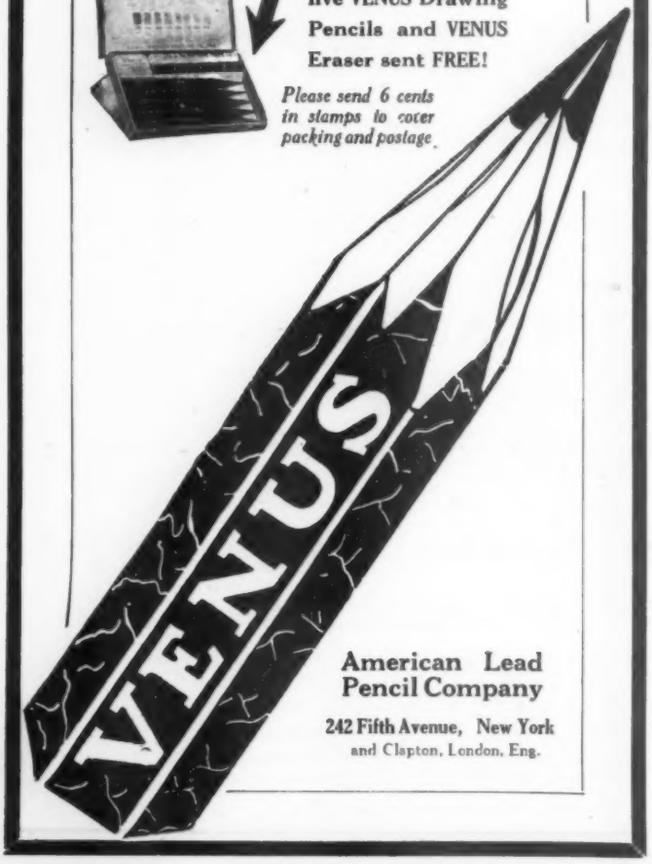

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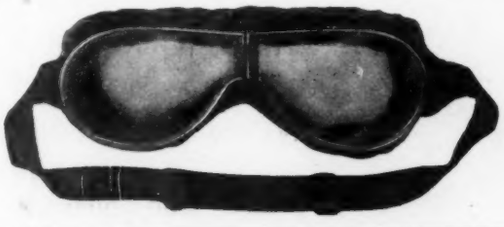

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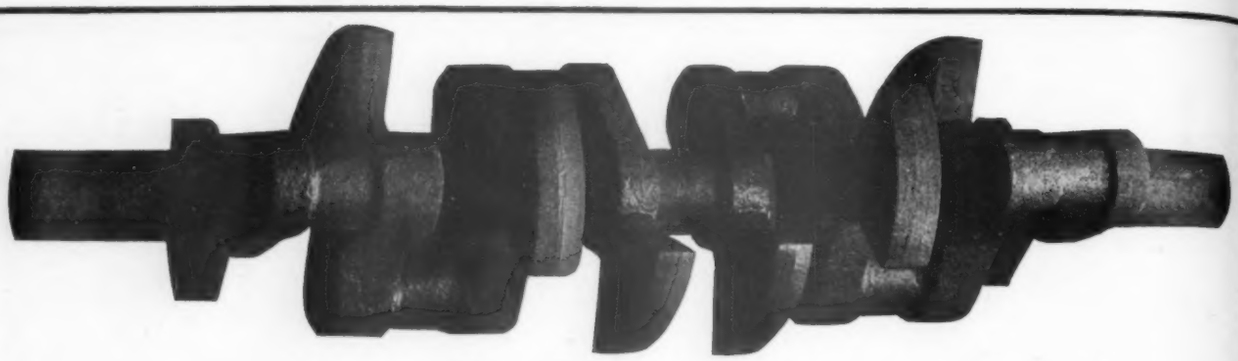

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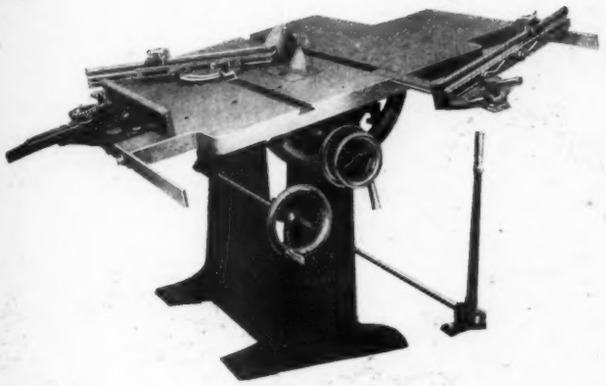

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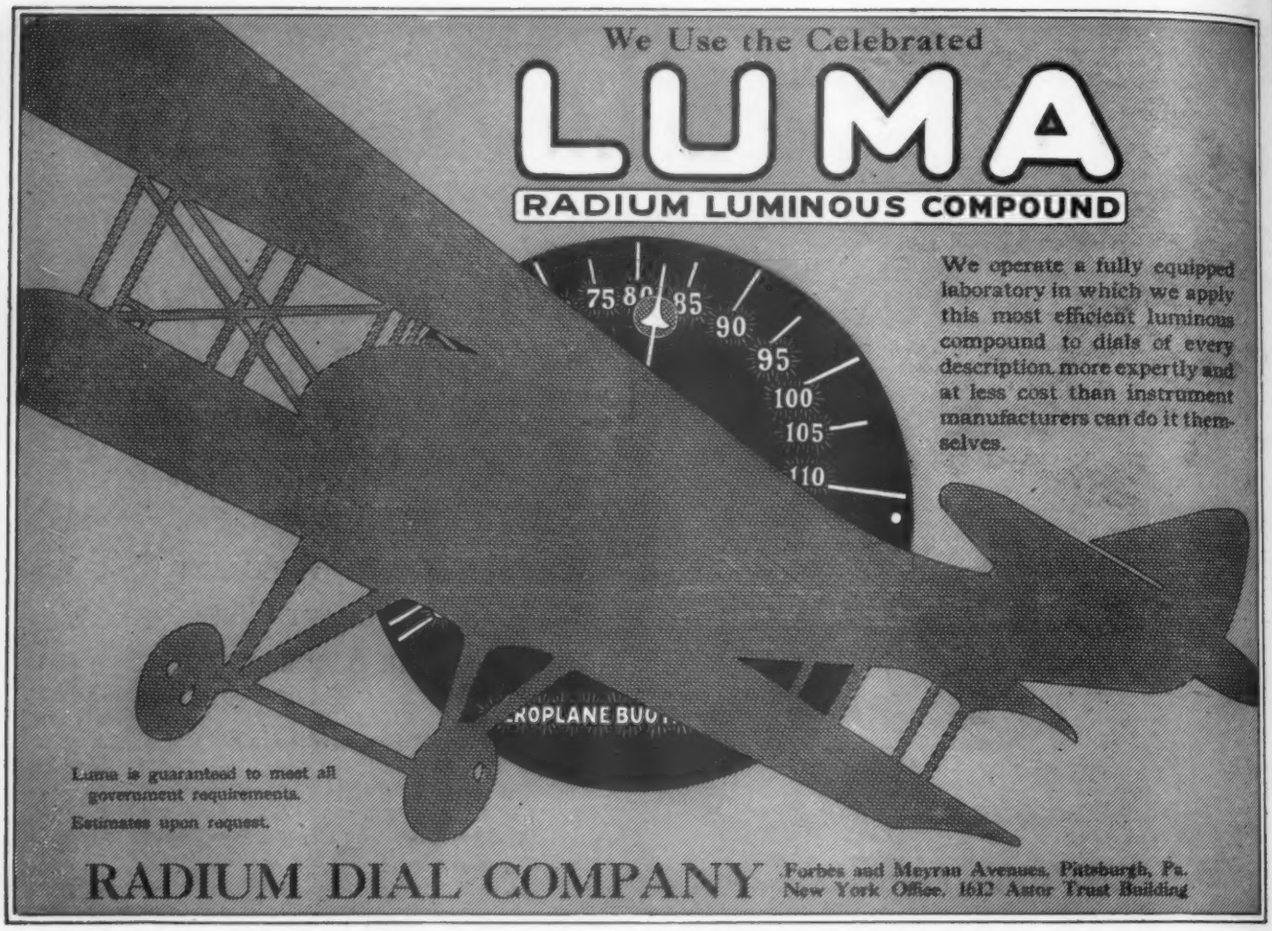
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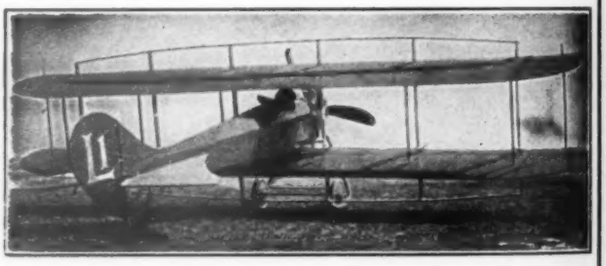

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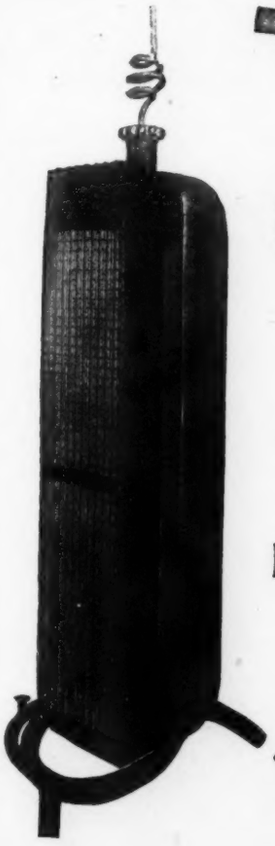

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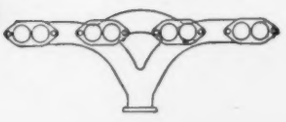

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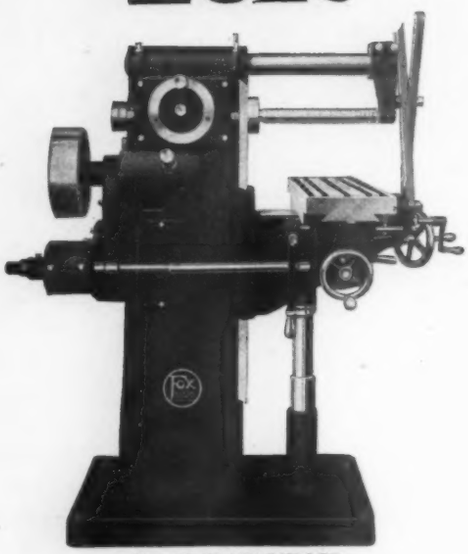

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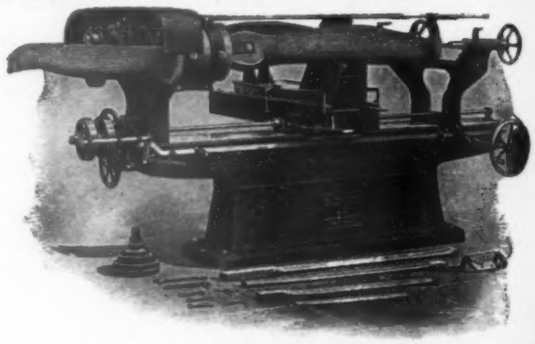

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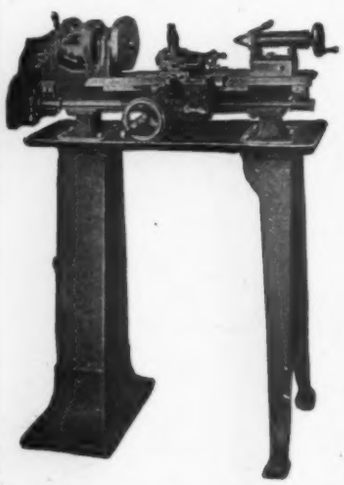

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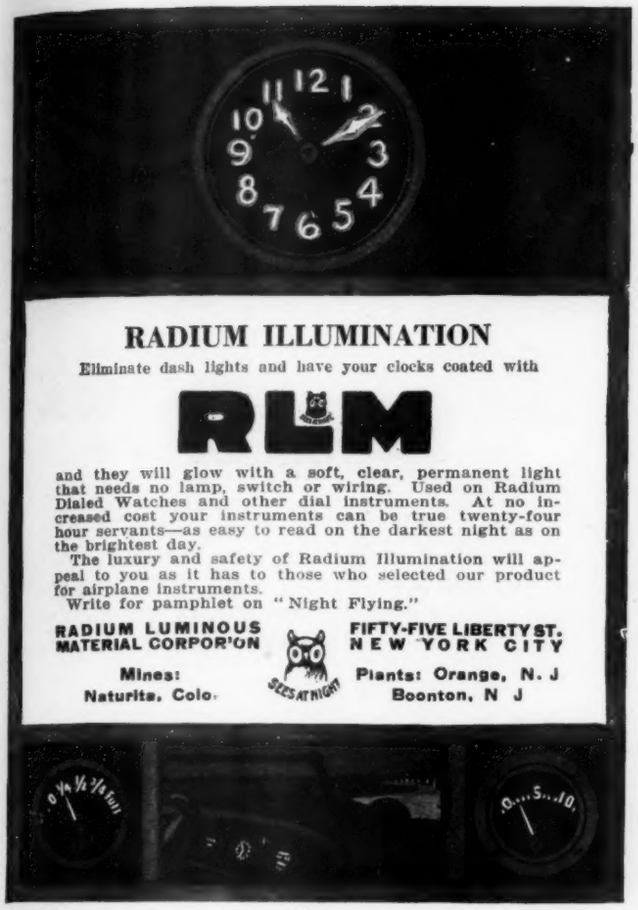

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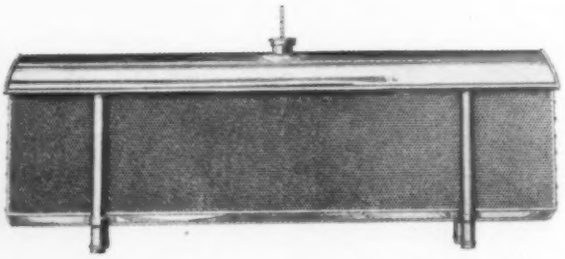

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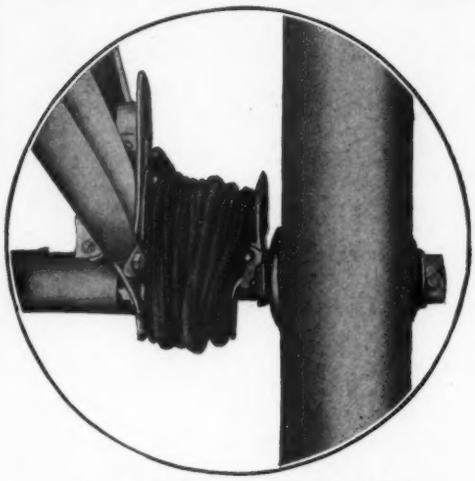

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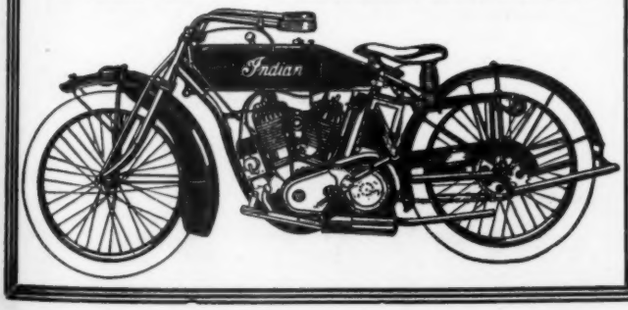

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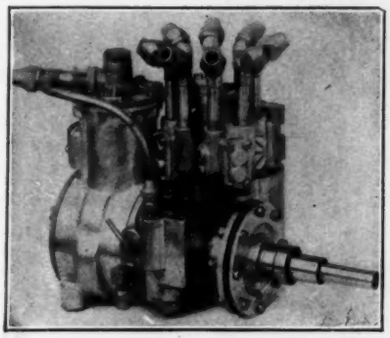

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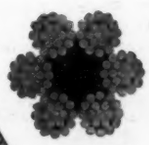

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General Rubber Goods Co.
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Wood, J. W. Elastic Web Co.

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Johns-Manville Co., H. W.
Stewart Warner Speedometer Corp.

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Wagner-Hoyt Electric Co.

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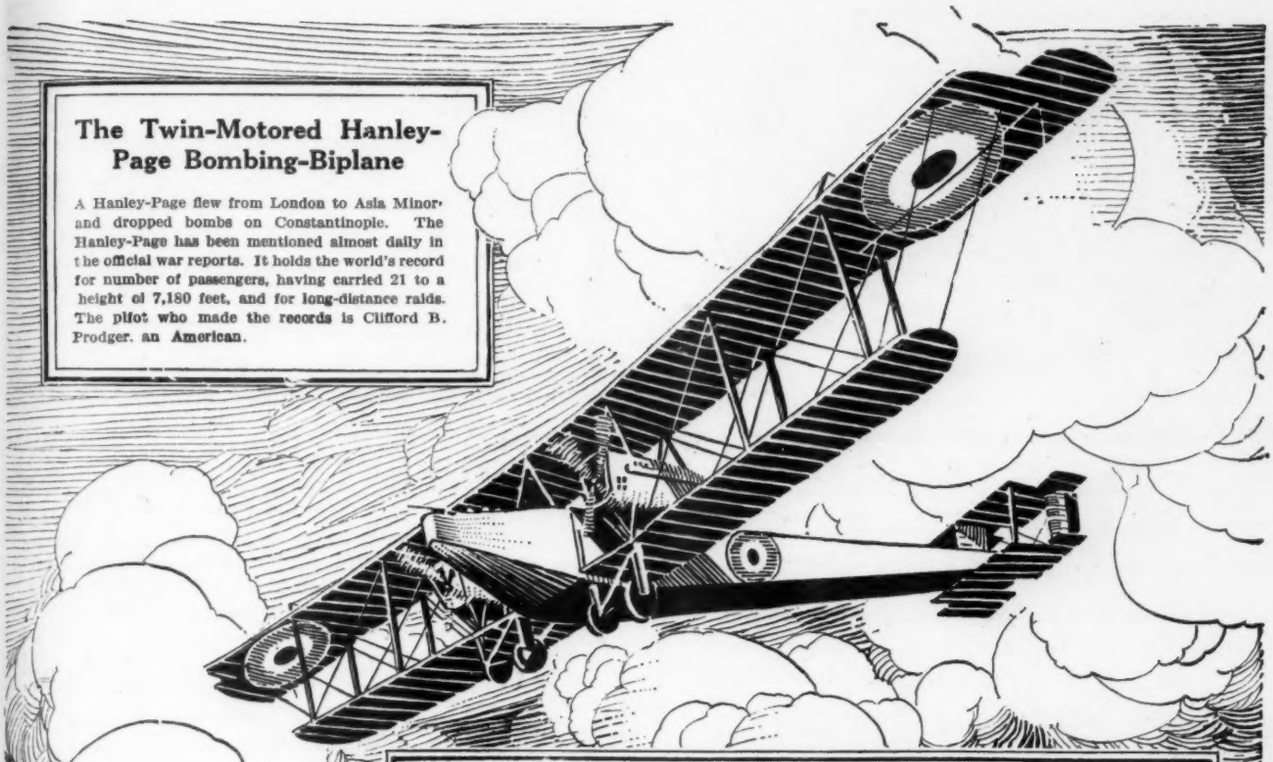

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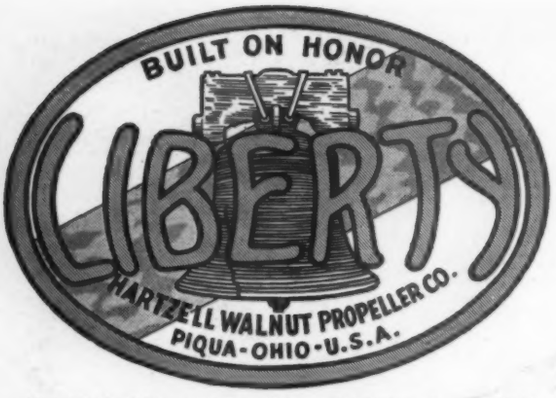

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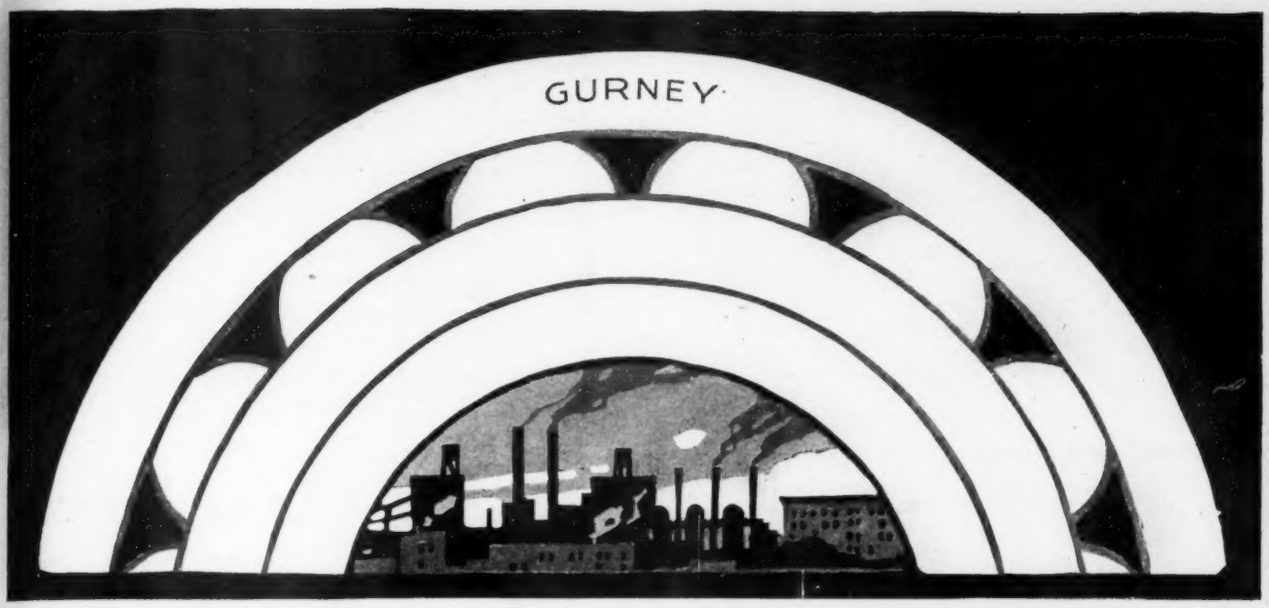

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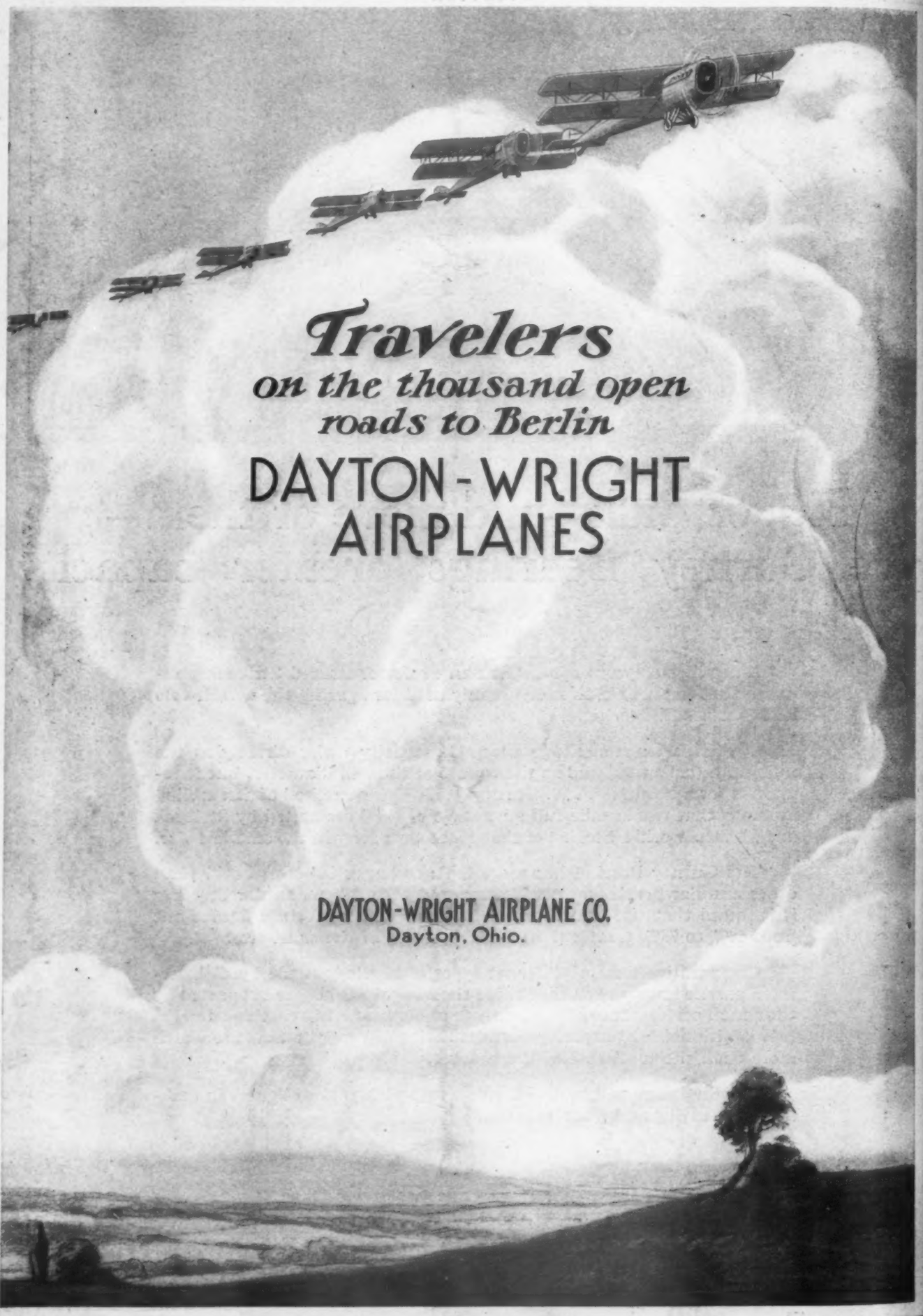
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